THE UNIVERSITY OF ALBERTA

Evaporation Losses from Crude Oils

by

P.M. Dranchuk.

FACULTY OF ENGINEERING

DEPARTMENT OF CHEMICAL AND PETROLEUM ENGINEERING

SEPTEMBER, 1959.

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THE UNIVERSITY OF ALBERTA

EVAPORATION LOSSES FROM CRUDE OILS

A DISSERTATION
SUBMITTED TO THE FACULTY OF GRADUATE STUDIES
IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE
OF MASTER OF SCIENCE IN PETROLEUM ENGINEERING

FACULTY OF ENGINEERING

DEPARTMENT OF CHEMICAL AND PETROLEUM ENGINEERING

by

P. M. DRANCHUK

EDMONTON, ALBERTA
SEPTEMBER, 1959.

UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES

The undersigned hereby certify that they have read and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled "Evaporation Losses From Crude Oils" submitted by P. M. Dranchuk, B. Sc. in partial fulfilment of the requirements for the degree of Master of Science in Petroleum Engineering.

ABSTRACT

The literature concerning evaporation losses from liquid petroleum has been reviewed with emphasis on that material dealing with the estimation and measurement of such losses. The available methods for determining evaporation losses have been examined in detail and their application to crude oils has been discussed.

The determination of refractive index of various crude oils and their residues was attempted. The results of such attempts are discussed.

A sample of crude oil from Alberta's Wizard Lake Field was exposed to controlled evaporation for varying lengths of time resulting in residues representing from approximately two to sixteen percent evaporation loss. The original crude oil and each of the evaporation residues were distilled by both the Hempel and Engler methods and the resulting distillate fractions and distillation bottoms were examined.

The use of distillation, API gravity midpercent and yield curves for the purpose of evaporation loss estimation is discussed.

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I. INTRODUCTION

The petroleum industry employs the term evaporation losses to describe the decreases in quantity of liquid petroleum resulting from the escape to the atmosphere of the lower boiling point constituents. Evaporation losses, for many years ignored, have more recently become increasingly important. The growing interest in these losses has stemmed from the increasing demand for fuels consisting of the lower boiling point constituents.

Attempts by petroleum producers to measure, estimate, reduce or eliminate evaporation losses from crude oils are first mentioned in the literature during the early 1920's. Since that time these problems have been the subject of numerous discussions and somewhat fewer investigations. These endeavors have not been nearly as successful as have those dealing with refined products. This is obviously due to the fact that crude oils pose problems which are technically more difficult and economically seemingly less important than are those for refined products.

Before serious attempts can be made to reduce or prevent evaporation loss there must exist a method of determing the quantity lost and thereby the value of the lost portion. To date there has not been a satisfactory method of estimating evaporation losses from crude oils. Measurement and estimation techniques though available are unsatisfactory since they are either inaccurate, impractical or too costly.

In view of the need for a satisfactory method of estimating evaporation losses from crude oils this project has concerned itself

with an examination of presently available methods and the possibility of estimating such losses by comparing refractive index, distillation, API gravity midpercent and yield curves for a partially evaporated crude oil to those for the same oil at some reference condition.

II. LITERATURE REVIEW

The loss of crude oil due to evaporation, although recognized, was for many years neither understood, nor given serious consideration but was merely accepted as a necessary evil. Although this topic was the subject of discussion before 1920, the first extensive investigation was carried out and reported in 1922 by Wiggins (27). In this paper he attributed the interest in this topic to the threat of a gasoline shortage in the United States during 1919. He showed the magnitude of evaporation losses to be of the order of 6.2 percent by volume. Besides suggesting methods of measurement and improvements in equipment and practices he emphasized the importance of these losses by demonstrating that the losses in the Mid-Continent Field alone were equal to 1.5 times the total natural gasoline production.

From 1922 to the present the magnitude and importance of evaporation losses have been topics of numerous discussions. Schmidt's (22) survey in 1934 showed that losses had been decreased from 6.2 percent to about 2.0 percent. The Oil and Gas Journal (20) though agreeing with Schmidt stated that although the decrease in losses was of the order of 41 million barrels per annum much remained to be accomplished. An investigation in 1937 by Tucker (25) showed that a stabilization temperature of 140°F resulted in a decrease in API gravity of 3.3 degrees. He emphasized that this temperature was the maximum permitted by the Texas Railroad Commission. Mauney and Vandaveer (16) (1938) demonstrated that large losses could be incurred by the processes of "rolling" and emulsion treating. They felt that Schmidt's (22) estimate of 2.0 percent was much too low, even for 1938. At this same time Ashley (3) upon surveying the topic came to the conclusion that the importance of the

problem had been realized and that efforts were being made to cope with it, but that such efforts lacked coordination. Bassler (8) in 1939 discussed the importance of evaporation and gravity losses. He attributed the eastern producers' lack of interest to the fact that refiners in the area, since they were primarily interesting in lubricating oil manufacture, did not subscribe to gravity price differential. After 1939 others such as the Oil and Gas Journal (19,21), Kallam (15), Williams (28), D'Aragon (10), Nelson (18), and Huntington (14) took up the task of informing the industry with regards to evaporation loss, with the result that the American Petroleum Institute established a committee to study this field. The Committee published its first findings in 1952 (1). Although this first work considered only the basic theory and mechanisms and their application to specific cases, it did establish that a great deal of work was yet to be done. The bibliography cited in their report is both extensive and excellent.

It is quite evident that once the need for prevention of evaporation losses was established, although it wasn't unanimously accepted, it did not go unheeded. The decrease in losses from 6.2 percent to 2.0 percent (22) came about through the conversion from open, wooden, storage facilities to closed steel tanks and in some instances vapor conservation balloons as described by Bignell (6,7). Tucker (25) disclosed that by 1937 stabilization and closed system emulsion treating were quite common. Kallam's (15) review of crude oil stabilization to the year 1943 showed that although these methods were known they were accepted very slowly.

Since both the need for decreasing or eliminating evaporation losses and the equipment necessary to satisfy this need were gradually established, why were they not accepted more rapidly? The literature

suggests a combination of reasons. Chenicek and Whitman (9), Mauney and Vandaveer (16), the Oil and Gas Journal (19,21), Williams (28), Viles and Jones (26), Hill (12) and the American Petroleum Institute (1,2), in their articles from 1930 to 1957, leave little doubt that one, if not the, important reason was the lack of an adequate method of determination of the exact magnitude of evaporation losses. Bassler (8) indicated that in certain regions the lack of acceptance was probably due to the fact that refiners did not establish gravity price differentials. Hill (12) pointed out that whereas evaporation loss - control to the refiner and pipeliner represents an immediate monetary gain to the producer, it represents a small immediate gain as a result of gravity conservation and a somewhat larger deferred gain as a result of volume conservation. It was to the producers' uncertainity of the magnitude of evaporation losses and the economic benefit to be realized from the prevention of such losses that he attributed the slow acceptance of evaporation control practices.

METHODS OF MEASURING AND ESTIMATING EVAPORATION LOSSES

Methods of measuring and estimating evaporation losses may be classified into a number of different types. The most logical classification seems to be that reported, in 1957, by the API (2). In this classification all methods are separated into four general types, viz., those methods dealing with;

1. decreases in stock volume.
2. changes in stock properties.
3. measurements of vented vapors.
4. special techniques.

It is evident from the literature that the general types of methods, with the exception of those dealing with special techniques, were known to Wiggins (27), and were indeed very well reviewed by Chenicek and Whitman (9), Ashley (3) and the API (2). Though the types of methods were generally known, the methods, themselves, were developed gradually.

All of the methods seem to have only one thing in common and that is that not one of them is completely satisfactory. It is felt that the application and limitations of the various methods can best be appreciated when they are examined in detail. The various methods are therefore presented and discussed in order of increasing importance.

1. Special Techniques

The general type of methods referred to as Special Techniques was first mentioned in 1957 by the API (2). In this type were included pilot scale tests and repeated transfer techniques. Although this source mentions only these two methods it is presumed that this type would include all those methods which involve simulated rather than actual systems.

Although simulation techniques have been known for many years and have been employed to solve other problems, there does not seem to be any evidence of their being used for the measurement of evaporation losses from petroleum. It is felt that this has been due to the nature of such technique rather than to an oversight on the part of the industry concerned. When it is observed that in order to effect simulation all the necessary variables must be controlled and therefore measured and that if such measured quantities were available the desired results could be obtained much more quickly and economically by

calculation than by simulation it becomes quite obvious that such techniques have a very limited field of application.

With the above observation as a basis it seems reasonable to assume that in the future such techniques, though they may be used in dealing with refined products and design problems, will see very limited application in the production and transportation of crude oil.

2. Measurements of Vented Vapors

This particular type of method was first mentioned by Schmidt (22). The various techniques of this type although thoroughly discussed (22,9,3,1,2), have never been employed very extensively.

Techniques of this type available at present are four in number, namely those involving,

(a) the sorption and measurement,
(b) the measurement of volume and the estimation of analysis,
(c) the measurement and analysis,
(d) the estimation of both volume and analysis,

of the vented vapors. With the exception of those instances in the first technique where the sorption medium is a liquid, the data must be processed to express the loss in terms of liquid volume.

These methods have not been widely accepted because of the following;

(1) estimation techniques, although well developed (13,1), yield results of limited accuracy since they involve the use of properties, materials, and conditions of operation which are extremely difficult to measure.
(2) analysis techniques are both time consuming and expensive.
(3) measurement techniques,
  (i) require elaborate facilities, if accurate results are to be obtained.
  (ii) require that all of the vapors must pass through the measuring equipment.

(iii) may impose conditions on a system such that the evaporation conditions may be sufficiently altered to nullify the results.

(iv) involve facilities which are cumbersome and costly.

(v) are time consuming and expensive.

For these same reasons it does not seem likely that the use of these methods will increase rapidly in the future.

3. Decreases in Stock Volume

Methods of this type, though no doubt known much earlier, were used and mentioned by Wiggins (27). The available methods were discussed and examined by Wiggins (27), Chenicek and Whitman (9), Schmidt (22), Ashley (3) and the API (2).

All the techniques of this type involve the measurement of liquid volume before and after loss due to evaporation has occurred. They differ only in the manner in which volume is determined.

Until recently volumes were measured by determining the depth of liquid in a "strapped" or calibrated vessel with the aid of a steel tape or hook gage, and making appropriate temperature corrections. A method which has recently received limited acceptance employs positive displacement meters. The determination of volume from measurements of hydrostatic pressures is being developed (2).

Since methods of this type were used in the determination of volume for the purpose of custody transfer it would, at first glance, appear that they should have been adequate for the measurement of evaporation losses. The literature (9,22,3,2) indicates, however, that the adequacy of such methods was continually questioned. The objection to these methods dealt with measuring accuracy, losses due to other causes, measurement before evaporation, presence of foreign materials, and measurements in working storage. Though these objections were

voiced and discussed no one source contains a complete discussion of all of the objections. For this reason each of the objections warrants examination.

(a) Accuracy

The accuracy with which volume measurements may be obtained through the use of calibrated tanks and steel tapes or hook gauges is dependant upon, the accuracy of the tank calibration, the effects of time and temperature on the volume of the tank and the accuracy of the tape or gauge, and the care with which the tape or gauge is used. The suggestion by Schmidt (22) that extreme accuracy could be realized if gauges were read to the nearest thirty-second of an inch and the appropriate corrections were made to account for changes in tank volume and gauge length due to temperature variation is misleading, since it confuses precision with accuracy.

The hand gauging technique is at present used almost exclusively for the determination of volume for custody transfer purposes. The accepted practice consists of reading the gauge to the nearest one quarter inch and often times to the nearest one half inch with no gauge length or tank volume correction for temperature variation. This practice is based upon experience which has shown, that temperature corrections, for other than liquid expansion or contraction, although important are impractical in field operation because of the data required. It has also been shown that the reading of gauges with greater precision than presently used does not increase the measuring accuracy appreciably. This is due to the presence of other variables such as temperature, heights of tank bottoms and roofs and settling of tanks. The accuracy attained with the use of these techniques

is probably of the order of one to two percent as compared to the three hundredths of one percent suggested by Schmidt (22).

Recent studies in "automatic custody transfer" indicate that in the future measurement will be effected by means of some form of positive displacement meter with a measuring accuracy of one percent or better. On this basis it seems that the measurement of volume with an accuracy of one half of one percent is not unrealistic.

Although volume measurement techniques of greater accuracy were and still are desirable the available techniques cannot be thought of as inadequate for the purpose of evaporation loss determination on the basis of measuring accuracy. The folly of suggesting techniques for evaporation loss measurement of greater accuracy than that used for custody transfer is evident. Such suggested techniques have at least in part been responsible for the lack of acceptance of evaporation loss control.

(b) Losses Due To Other Causes

One of the more important shortcomings of all evaporation loss determination techniques involving the measurement of decreases in volume is that such techniques cannot distinguish between losses due to evaporation and losses due to other causes. That variation in volume could result from leakage or spillage of oil or water out of a storage vessel has been well known. The effect of such volume changes on the determination of evaporation losses has been discussed by Chenicek and Whitman (9) and Ashley (3) but because of its obvious nature has received much less literature coverage than has measuring accuracy even though it is the more important.

(c) Measurement Before Evaporation

The most serious objection to the techniques under discussion stems from the fact that, in the production of crude oil in particular, it has been virtually impossible to determine liquid volume before evaporation has occurred. These techniques have not provided a means of detecting those losses that occur as a result of treating, handling and other production practices. It is primarily on this basis that these techniques must be deemed wholly inadequate.

Tucker's (25) demonstration that emulsion treating could result in a decrease in API gravity of 3.3 degrees and Mauney and Vandaveer's (16) indication that a decrease of 1.0 degrees API resulted in a volume decrease of approximately 2.6 percent coupled with the fact that such losses are not normally detected by volume measurement, demonstrates the shortcomings of the techniques in question. The literature, however, contains no specific discussion of this topic.

(d) Presence of Foreign Materials

The presence of foreign materials such as water and or solids may have a direct bearing on the application of volume measurement techniques, only in the instances that they enter the measuring vessel subsequent to its being filled. Indirectly, such materials affect evaporation detection by volume measurement techniques only in those cases where removal of these materials may cause evaporation not detectable by these means and where the accumulations of such materials may affect gauging accuracy.

(e) Working Storage

Any facility used for the storage of a material in such a manner that the residence time of the material is short as compared to

the time required to fill and empty the facility, is referred to as working storage. Surge tanks, "rundown" tanks and crude oil production tanks are examples of this type of facility.

Since material is almost continually being transferred to or from working storage determinations of volume in such facilities are more difficult and less accurate than they are in standing storage. The determination of evaporation losses from working storage by means of hand gauging, even in those instances where elaborate inventory taking techniques are employed, is virtually impossible.

When it is observed that accurate inventories have been unobtainable in the production of crude oil it is understandable that the application of hand gauging techniques to evaporation loss determination in this field wasn't successful. Although the inadequacy of such techniques is discussed by Chenicek and Whitman (9) and the API (2) it is suggested by the API (2) that the development of accurate positive displacement meters may permit the determination of evaporation losses by volume measurement techniques.

In summary it is observed that the determination of evaporation losses, from produced crude oil, by the measurement of stock volumes has not been and presently is not a reliable practice. Furthermore, because of the numerous shortcomings of such techniques, it seems unlikely that the perfection of an accurate displacement meter will increase the reliability of such methods to the point where they may be considered adequate.

4. Changes in Stock Properties

Since Wiggins (27) observed changes in distillation and Baume gravity curves resulting from losses due to evaporation, there have been

numerous attempts to estimate such losses by observing changes in stock properties. Some of the properties examined have been;

(a) Specific gravity
(b) Baumé gravity
(c) API gravity
(d) density
(e) distillation temperature
(f) vapor pressure
(g) refractive index

The methods of observation and interpretation employed by the various investigators have been both varied and numerous. These methods are herein examined in detail on the basis of the property examined.

(a) Specific Gravity

Wiggins (27) made the observation that losses increased the specific gravity of a crude and that if the specific gravities of the crude oil before and after evaporation along with that of the evaporated portion were known the percent volume lost could be calculated. Since it was impossible to measure the specific gravity of the evaporated portion he devised a method of estimating this quantity from distillation data.

The method for estimating the specific gravity of the evaporated portion consisted of the comparison of the Baumé gravity midpercent curve for the oil before evaporation with that after evaporation. Since the two curves were of similar shape it was proposed that the portion of the curve for the unevaporated crude above the initial point of the curve for the evaporated crude represented the evaporated portion. The gravity was then obtained by integral averaging.

It is felt that such a method is not valid for two reasons. Firstly, Baumé gravity, since it is not an additive property (17), does not lend itself to integral averaging and therefore, strictly

speaking, should not be averaged, neither, for the construction of midpercent curves nor for the obtaining of an average value for a finite fraction. Secondly, the assumption that the upper portion of the curve for the unevaporated crude in fact represents the evaporated portion is only true when the evaporation and distillation processes are identical. Since a large variation is possible in both processes it is questionable whether such an assumption can be deemed valid for a variety of cases, despite its validity in the case cited.

This method of estimation is discussed by Chenicek and Whitman (9) and Schmidt (22).

(b) Baumé Gravity

The estimation of evaporation losses from a comparison of Baumé gravity midpercent curves is suggested by Wiggins (27). In this work Baumé gravity midpercent curves were established for the unevaporated and evaporated crude oil. It was found that the two curves were similar in appearance and that if the values of percent distilled, for the curve obtained from the evaporated crude, were divided by (1-x), x being the volume fraction lost due to evaporation, the curve resulting was nearly parallel to that for the unevaporated crude. It was then demonstrated that a point could be found such that the horizontal separation between the two curves was equal to the evaporation loss.

This method as cited requires the knowledge of the extent of evaporation loss if the required correction is to be made. This could probably be circumvented by merely rotating the curve, for an evaporated crude, about the initial point into a parallel position with regards to the reference curve. The validity of this or the

original method cannot be fully discussed on the basis of the original work since only two curves, viz., the reference curve and one evaporation curve, were presented.

It appears that shortly after Wiggins' (27) paper the petroleum industry adopted the API gravity scale to replace the Baumé scale. In any event there is no further mention of the use of Baumé gravity for the estimation of evaporation loss.

(c) API Gravity

The use of the change in API gravity of a stock for the purpose of estimating evaporation loss no doubt resulted from the early work on Baumé gravity. The use of the API gravity for estimation of losses was first mentioned by Chenicek and Whitman (9) who stated that good estimations could be made for large losses but that a knowledge of the effect of loss on gravity for any stock was necessary. They observed that for gasolines a change of 1 degree API was accompanied by a volume loss of 2.5 to 3.0 percent. Tucker (25), in reviewing stabilization practices, observed that by increasing the temperature of crude oils to 140°F a decrease of 3.3 degrees API could result.

The first attempt to correlate changes, in API gravity and volume, resulting from evaporation was made by Mauney and Vandaveer (16). By plotting "Degrees API Loss versus Percent Volume Change" they established a linear relationship such that a 2.6 percent decrease in volume resulted in a 1.0 degree decrease in API gravity. Bassler (8), however, plotted "API Gravity versus Loss Percent", for seven different crude oils and demonstrated that the relationship was not generally linear, but that API gravity decreased with volume at a decreasing rate. The latter data were obtained by calculation from distillation results.

The method of calculation and the use of the resulting data for the estimation of evaporation loss was suggested but no comparison was made between this work and that of Mauney and Vandaveer (16).

Whereas Mauney and Vandaveer (16) carried out field investigations and Bassler (7) proposed the examination of distillation data, Huntington (14) examined seven Oklahoma and Texas crude oils by placing them into 1000 millimeter open cylinders and permitting atmospheric evaporation over long periods of time. By plotting "Volume versus API Gravity" he found that as evaporation progressed the differential shrinkage per degree API increased from about 2.0 to 9.0. He observed that the previously accepted ratio of 2.5 was in error. Although he suggested that the variation in the differential shrinkage per degree API could be attributed to the variation in composition of the evaporated portion he did not compare his observations with those of Bassler (7) nor did he suggest the use of such observations for the purpose of evaporation loss determination.

Since API gravity has long been taken to indicate roughly the composition and therefore the quality of a crude oil its use for the estimation of evaporation losses has long been favored. It is quite evident that a differential shrinkage per degree API of 2.5 has been used to estimate evaporation loss (28). Hill (12) pointed out that its use is satisfactory where accuracy is not too important. He suggested that for more exacting estimations the relationship of volume loss to API gravity loss should be established for each case as this relationship is dependant upon the manner in which evaporation occurs.

Though both the abovementioned approaches have been known and used neither has gained wide acceptance. This lack of acceptance was

probably due to the fact that the relationship of API gravity to volume is dependant upon composition and method of evaporation as well as the fact that volume and API gravity changes accompany phase separations other than those due to evaporation. The latter factor has posed the question of separating those effects due to oil gas separation and those due to evaporation. As a result there has not been developed a method of determining a reference point or point of zero evaporation loss.

(d) Density

The use of changes in density as a means of estimating losses due to evaporation was recently suggested by the API (2). This method proposes that a sample of unevaporated stock be subjected to controlled evaporation by bubbling air through it. A periodic examination of the volume and density of the sample permits the establishment of a relationship between the density and volume percent loss. Such a relationship may then be used to estimate evaporation loss from the stock in question.

It is felt that although this method may be quite satisfactory for refined products it is not satisfactory for crude oils. This thinking is based on the fact that this method is similar to those cited, employing specific, Baume and API gravities and as a result suffers from the same inaccuracies. These inaccuracies stem from the assumption that the compositions of the unevaporated stocks remain essentially constant and that the process of evaporation employed in developing the relationship to be used for the purpose of estimation is identical to the actual evaporation process.

(e) Distillation Temperature

The use of temperature or distillation curves was suggested by Wiggins (27). The method proposed was very similar to that suggested by

him concerning the use of Baume gravity midpercent curves. It consisted of measuring the separation between a corrected curve for an evaporated stock and a curve for the unevaporated stock. This method poses a difficulty similar to the one concerning the use of Baume gravity curves in that the correction of the curve for the evaporated stock is of necessity a trial and error procedure. The fact that the method lacked confirmation since only two curves were presented was also common to both methods. A further disadvantage of this approach lies in the fact that in general distillation curves are not as smooth as are gravity or density curves since the accurate measurement of temperature is more difficult than is that of gravity or density.

There is evidence that the change of slope of the USBM distillation curve at the 10 percent point was used as a basis for evaporation loss determination. Other than Ashley's (3) statement to the effect that in 1938 this method was no longer used because of its inaccuracy, information concerning this method does not seem to be readily available.

Methods of evaporation loss estimation from temperature or distillation data were evidently neither as well examined nor accepted as those employing gravity. This appears to have been due to the fact that the methods developed did not seem to be in any way superior to those employing gravity (9), but had a slight disadvantage in that temperature data were not as useful as were gravity data for determining the general quality of a stock.

(f) Vapor Pressure

The use of changes of vapor pressure of a stock for the estimation of evaporation loss was first suggested by Stauffer, Roberts

and Whitman (24) and was subsequently applied and discussed by Chenicek and Whitman (9). The original paper proposed a method whereby vapor pressures could be determined for any one sample with different percentages evaporated therefrom. The evaporation within the equipment was effected by bubbling air through the sample and the absolute vapor pressure was obtained by means of manometers. Successive evaporations and determinations were made until approximately 5 percent had been evaporated. When the data obtained were plotted on semi-log paper as vapor pressure versus percent evaporated a smooth curve resulted.

This method of examination was applied to an unevaporated stock and to samples of the stock which had suffered varying degrees of evaporation loss. The evaporation data obtained from the examination, when plotted simultaneously, resulted in a family of almost parallel curves. It was shown that the average separation between these curves could be used to estimate evaporation loss.

This method was subsequently discussed by Schmidt (22), Ashley (3) and the API (2). In the API work, however, the use of a modified Chenicek-Whitman apparatus was suggested. The discussions leave little doubt that the method is accurate for the estimation of small losses from refined products other than pure compounds and narrow fractions.

There is no evidence of the acceptance of this method for the estimation of evaporation losses from crude oils. This method, if used, would encounter similar difficulties to those encountered using the API gravity method. It would have the added disadvantage of using delicate, cumbersome and stationary test equipment. As such, this

equipment is not suitable for field use.

A method for the estimation of evaporation losses from refinery surfaces was presented by Viles and Jones (26). They recognized that the evaporation of an oil into a stream of air represented a diffusion process. Accordingly, they assumed the principal variables influencing the rate of such air evaporation to be, the vapor pressure of the oil and the air velocity. Using laboratory data obtained on various refinery waste oils they plotted rate of evaporation per unit area as a function of vapor pressure using wind velocity as a parameter. They then demonstrated that with such a correlation and a knowledge of vapor pressure, average wind velocity, the area of the free surface and exposure time the evaporation loss could be estimated.

Since it was felt that at that time no adequate vapor pressure determination procedure was available, a method for estimating it was designed. The method used, consisted of performing a true boiling point type distillation, converting the fractions to a mole basis by means of a correlation of volume per mole as a function of average boiling point and calculating the vapor pressure using a Cox type correlation of vapor pressure versus temperature with boiling point as a parameter.

This method, though different, is no more applicable than is that of Chenicek and Whitman (9) since the true boiling point apparatus is more cumbersome, costly and stationary than is the vapor pressure apparatus.

(g) Refractive Index

Benkovskii (5) observed that refractive index, since it is an additive property, could be used to determine evaporation loss. He stated that a crude oil could be considered as being a binary system

composed of that fraction that became lost as a result of evaporation and that fraction which remained after evaporation. He showed that if;

n_o = the refractive index before loss occurred

n_1 = the refractive index after loss occurred

n_2 = the refractive index of the lost portion

a = volume fraction of evaporation residue

b = volume fraction of the lost portion

then:

$$n_o = an_1 + bn_2 \tag{1}$$

He then suggested that if a small quantity (volume fraction = c) of a third component of refractive index n_3 were added to the original crude oil the refractive index of the resultant mixture became n_c and,

$$n_c = an_1 + (1-a-c)\, n_2 + cn_3 \tag{2}$$

He concluded that if c were sufficiently small so that the a's in equation (1) and (2) were essentially equal then the two equations could be combined to solve for a, as follows:

$$a = \frac{cn_o + n_c - n_o - cn_3}{cn_1 + n_c - n_o - cn_3} \tag{3}$$

By means of another mathematical approach he suggested that the quantity a could also be calculated as follows:

$$a = \frac{(n_3 - n_o)}{(n_3 - n_1)} + \frac{K}{100} \tag{6}$$

Where: K is a constant dependant upon the ratio $\frac{b}{c}$.

It was reported that this method had been successfully applied to numerous USSR crude oils. Mention was made of the fact that in several instances the use of this method resulted in large errors because the crude oils examined did not behave as additive mixtures. It was suggested that in such instances a laboratory evaporation be conducted until the refractive index of the residue is identical, to that of the evaporated crude oil and that the loss due to evaporation be calculated in this manner.

Since there is no other mention of this method it does not seem that it has been adopted to an appreciable extent.

Casual examination of this method suggests that it suffers from most of the disadvantages of the specific gravity methods. It is superior, however, on the basis that the equipment can easily be transported. It may also be superior if refractive index can be measured with greater accuracy than can specific gravity. In any event the method warrants further investigation.

III EXPERIMENTAL EQUIPMENT

Since the investigation was directed toward the development of techniques which could be applied in the field, most of the equipment employed consisted of readily available components which could be transported and assembled at a field installation. The choice of volume and gravity determination equipment was, however, based on a desire for more accurate results than would normally be obtained in a field test.

Refractive Index Apparatus

Refractive index was observed with a Bausch and Lomb Abbe - 3L refractometer. The refractometer was maintained at constant temperature by means of a 2.5 gallon capacity Precision Scientific Number 66600 constant temperature circulating bath, shown in figure 1.

In order to maintain the temperature of the bath below that of the surroundings the bath was modified by the addition of a one-sixth horsepower Universal Cooler Company refrigeration unit. The combined unit was so assembled that the water cooling coil of the original bath served as the evaporation coil for the refrigeration unit, as indicated in figure 2.

It was found that, with constant refrigeration and intermittant, thermostatically controlled, heat input, the modified bath was capable of circulating 60 ± 0.1°F water at rates up to 3 gallons per minute.

Evaporation Apparatus

The apparatus used to effect controlled evaporation was similar to that suggested by the API (2), in the density change method. The actual apparatus, as shown in figure 3, consisted of a nitrogen cylinder with standard pressure regulator, a needle valve, a Matheson Company

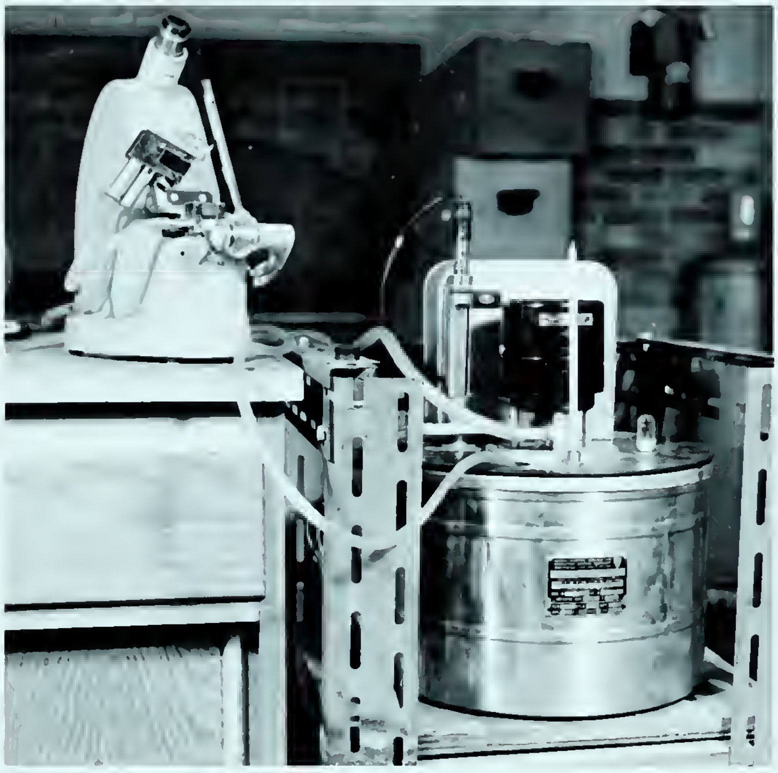

Figure 1 REFRACTOMETER AND BATH

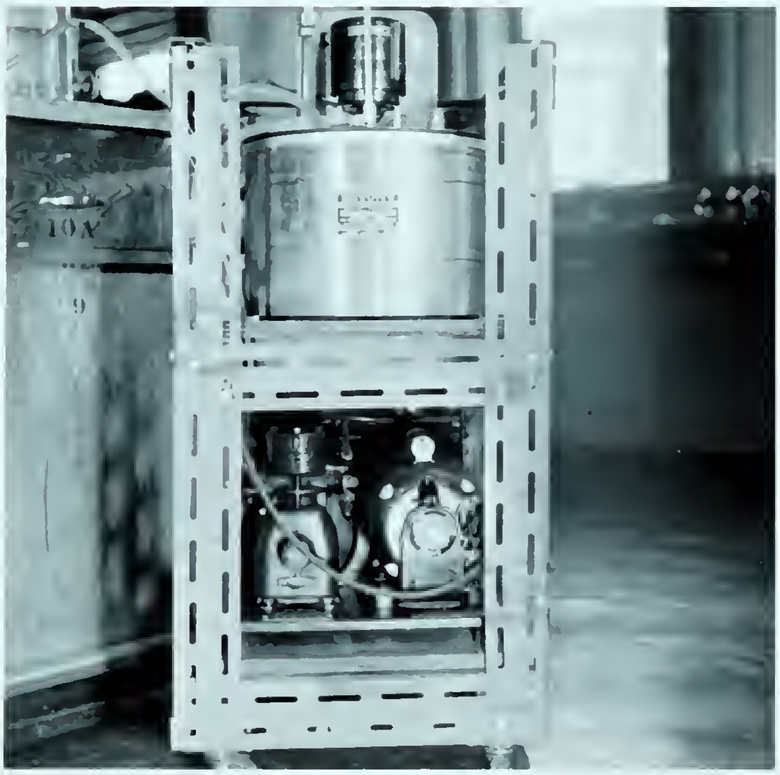

Figure 2 MODIFIED CONSTANT TEMPERATURE BATH

0 - 10 CFH air rotameter, a standard one liter three neck distilling flask with ground glass joints, two ground joint extension tubes, a specially blown aerating tube with perforated bulb and ground joint fitting, a magnetic stirrer with a teflon coated bar and a 2 kilogram analytical balance.

The perforated bulb of the aerating tube was positioned at about the center of the evaporation flask as shown in figure 4. A perforated rather than a sintered bulb was used, since it was felt that a sintered bulb would be difficult to clean. Although it was realized that the use of a sintered bulb might have increased the rate and uniformity of evaporation, it was felt that the use of a perforated bulb, with constant agitation by means of a magnetic stirrer, would yield adequate results.

Distillation Apparatus

Two types of distillations were conducted so as to observe the effect of the degree of fractionation on the distillation and property curves. In both methods a modified ASTM (4) apparatus was used, as indicated in figure 5. The modifications common to both methods consisted of, a covered polyethylene funnel adapter, at the exit end of the condenser, and a constant temperature distillate receiving apparatus. Both modifications, shown in figure 6, were designed to minimize distillation losses.

The first method of distillation, referred to as the Hempel type, employed a distillation flask, fractionating column, condenser, board and support, source of heat and a thermometer of the type prescribed by the ASTM (4). These components were assembled as shown in figure 7. This method was modified by removing the fractionating column to form the second method, shown in figure 8, and referred to,

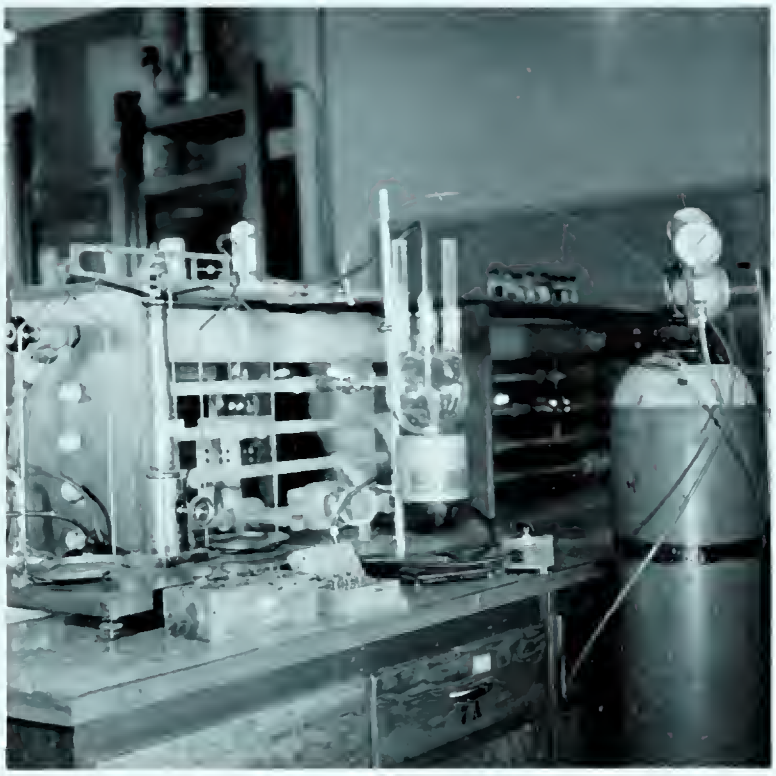

Figure 3 EVAPORATION APPARATUS

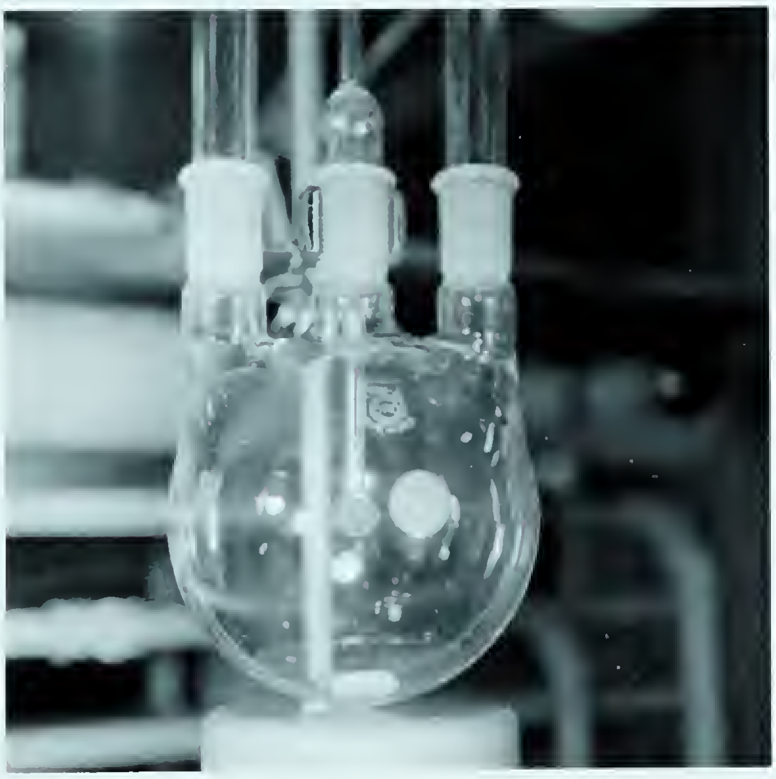

Figure 4 EVAPORATION FLASK

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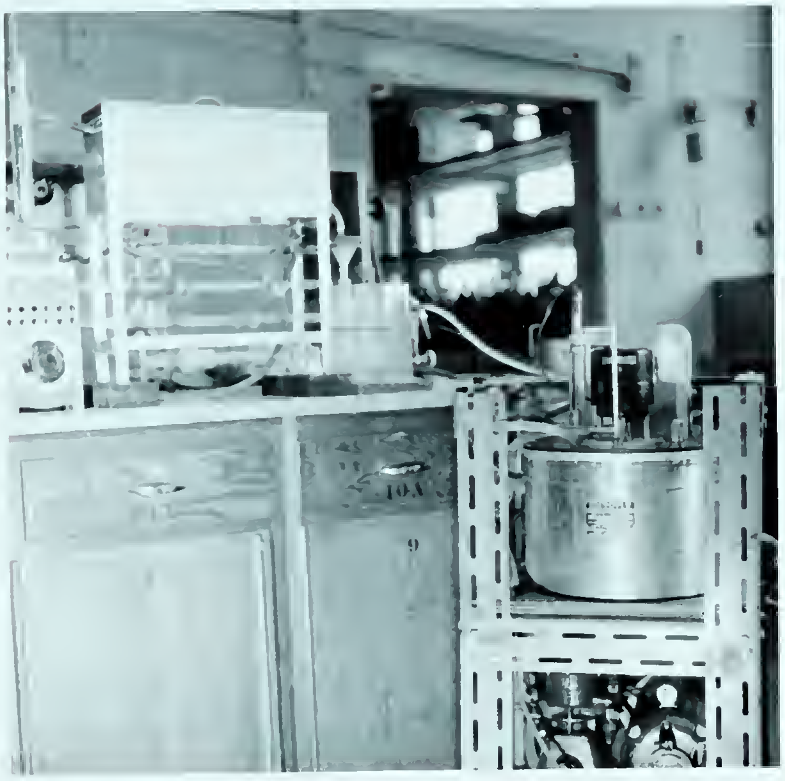

Figure 5 DISTILLATION APPARATUS

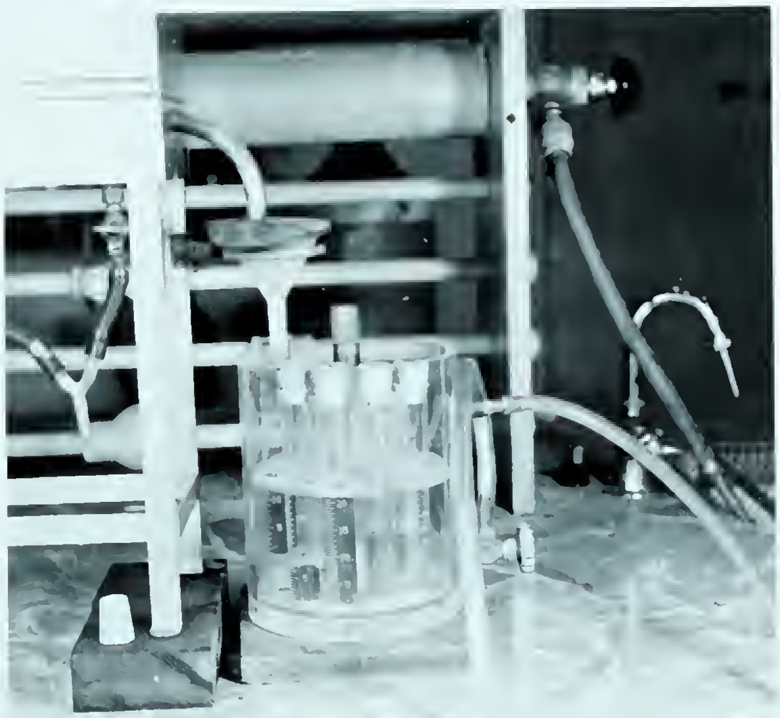

Figure 6 MODIFICATIONS OF DISTILLATION APPARATUS

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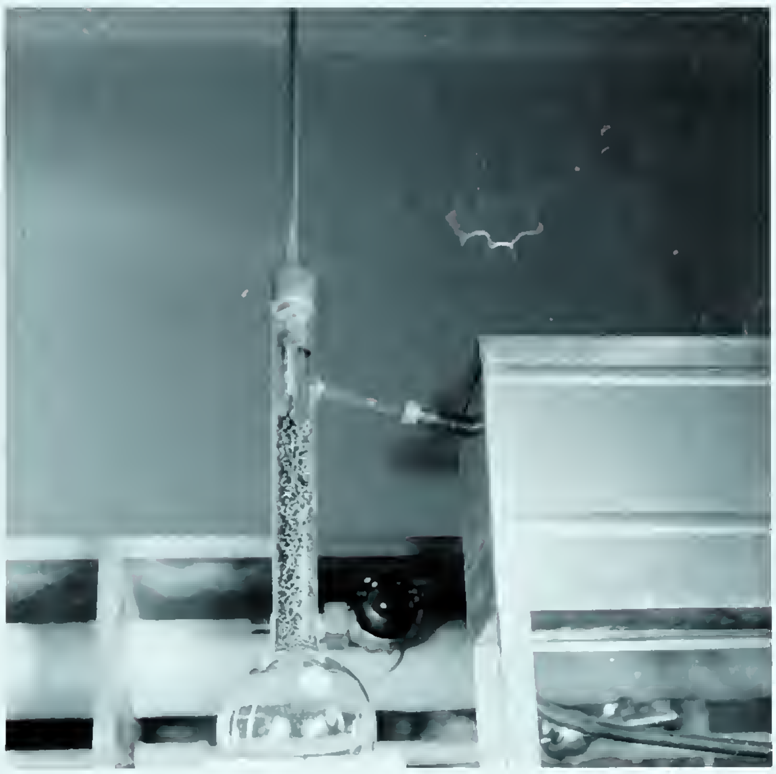

Figure 7 HEMPEL FLASK AND COLUMN

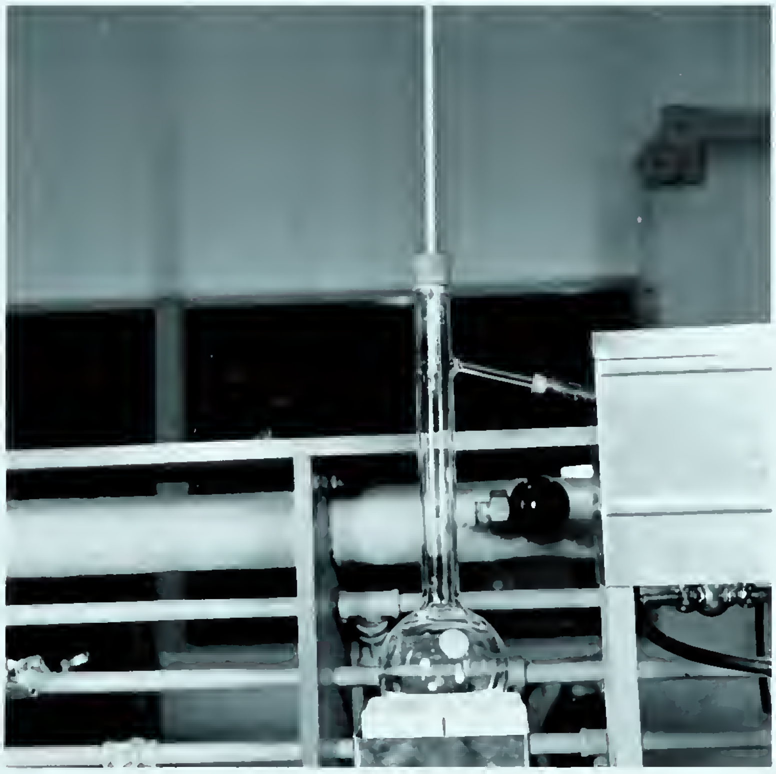

Figure 8 ENGLER FLASK AND COLUMN

[illegible]

[illegible]

in this paper, as the Engler type.

Distillate Receiving Apparatus

To facilitate the collection of small fractions, 25 milliliter graduated test tubes, with 0.5 milliliter subdivisions, were used as receivers.

It was found that by constructing a circular test tube holder and by placing it, on a pivot, in a water bath, the receivers could be changed rapidly while they were being maintained at a constant temperature. The actual design, as shown in figure 9, consisted of a lucite rack, capable of holding twelve receivers, centrally pivoted in a small cylindrical lucite tank, through which water could be circulated.

The circulating constant temperature bath mentioned under Refractive Index Apparatus, and shown in figure 2, was used to circulate water through the receiver changing apparatus. When circulation through the apparatus was first attempted the empty receivers were bouyed up by the water thereby making the changing of receivers impossible. This difficulty was alleviated by bonding sheet styrafoam to the upper disc of the test tube holder and cutting the corresponding holes so that they were of slightly smaller diameter than that of the receivers. The styrafoam provided the friction necessary to prevent the tubes from being bouyed up.

Specific Gravity Apparatus

Specific gravities of the crude oil, evaporation residues and distillation bottoms were determined using 25 and 50 milliliter, Gay-Lussac type, specific gravity bottles. Specific gravities of all distillate fractions were obtained by means of pipette pycnometers as suggested by the USBM (23) and shown in figure 10. Pipette pycnometers

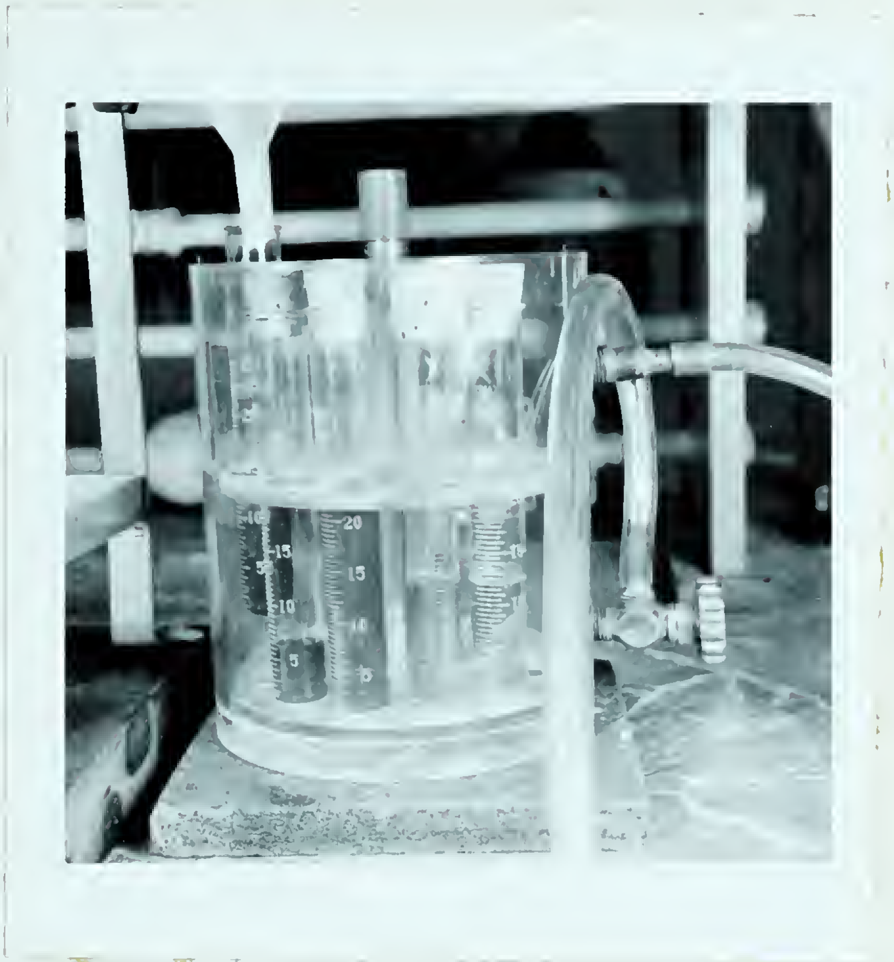

Figure 9 DISTILLATE RECEIVING APPARATUS

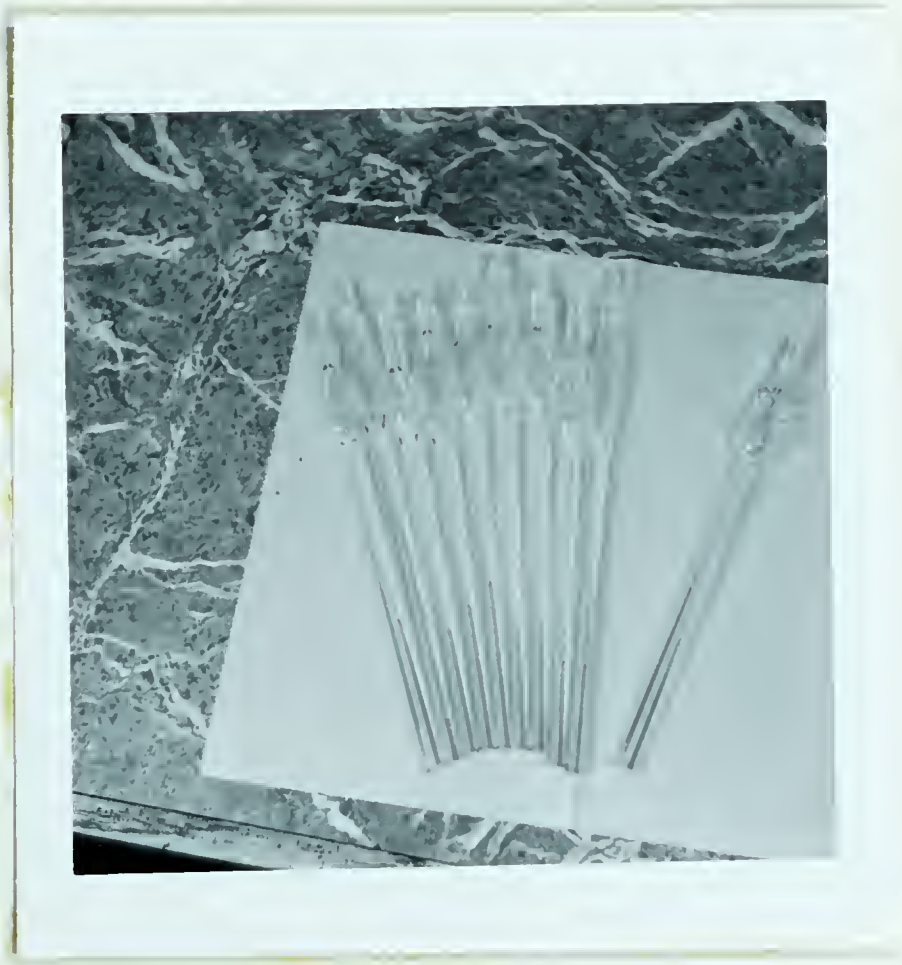

Figure 10 PIPETTE PYCNOMETERS

[illegible]

[illegible]

were chosen for this purpose since the samples to be examined were not sufficiently large to permit the use of a chain gravitometer.

All samples, on which specific gravity measurements were conducted, were maintained at constant temperature by means of the receiver changing and circulating constant temperature apparatus previously mentioned.

To minimize losses, due to evaporation, while specific gravity bottles and pycnometers were being weighed, a direct reading, Sartorious, analytical balance was used.

Sampling Equipment

Since numerous small samples of crude oil of constant composition were required for the investigation, it was decided to obtain one large sample and to remove small volumes as required. To insure constant composition it was necessary to choose a vapor - tight sample container from which small volumes of crude oil could be displaced with natural gas normally associated with the oil.

A 30 gallon steel drum was chosen as a crude oil sample container. This choice was based on the fact that the container could hold sufficient sample and could withstand internal pressures in excess of the vapor pressure of the crude oil.

To permit the introduction and removal of sample the large bunghole in the steel drum was fitted with a machined steel bung. Two holes were drilled through the steel bung. These holes were threaded to accommodate three-eighths and one-eighth inch brass pipe respectively. A length of three-eighths inch brass pipe was screwed into the underside of the bung so that with the bung in place the pipe extended to within one foot of the bottom of the drum. A three-eighths inch Jenkins, bronze,

angle valve, with a petroleum resistant disc, was fastened to the upper side of the bung by means of a short brass nipple. To the other opening on the upper side of the bung was fastened a one-eighth inch Hoke needle valve through a short brass nipple a stainless steel tee and another short brass nipple. The third opening in the tee was fitted with a 0 to 30 psi Marsh pressure gauge.

Both bungs were fitted with neoprene gaskets and securely fastened in place.

With the sample container assembled as shown in figure 11, it was then possible to introduce or remove liquid to or from a point one foot from the bottom of the container through the three-eighth inch angle valve and to introduce or remove vapor to or from the liquid surface through the one-eighth inch needle valve. The pressure within

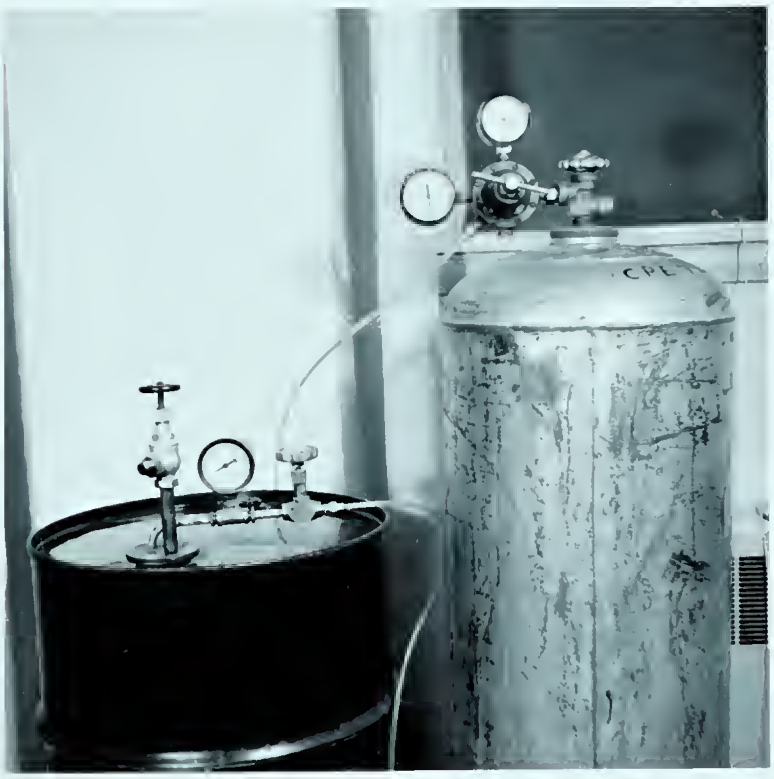

Figure 11 CRUDE OIL AND NATURAL GAS SAMPLE CONTAINERS

the vessel at any time could be observed by means of the pressure gauge.

Because of their capacity and working pressure two, commercial, 100 pound, propane cylinders were chosen as natural gas sample containers.

IV EXPERIMENTAL TECHNIQUES

In the interests of simplicity, accuracy and a view toward field application, readily available techniques were selected and where necessary modified to suit existing conditions.

Refractive Index

For the determination of refractive index of transparent distillate fractions the standard transmission method was found to be quite satisfactory. Where this method was not applicable because of the opaque nature of the liquids examined, a reflection technique, suggested by the instrument manufacturer, was employed.

Since the standard temperature for the measurement of volume, density, and gravity of crude oil is normally 60°F, measurements of refractive index were made at this temperature rather than at 25°C.

Refractometer prisms were cleaned by washing first with benzene, then with pentane and drying with commercially available lintless tissue.

Controlled Evaporation

Controlled evaporation was effected by placing the crude oil into the evaporation flask and agitating it continuously while nitrogen was bubbled through it at a constant rate.

The initial volume of sample charged to the evaporation flask was limited on the one hand by the size of the flask and on the other by the need of a certain minimum volume of resulting residue. It was found that a suitable initial sample volume was of the order of 900 milliliters. By choosing such an initial volume of sample, setting the stirrer at a control setting of 6, the nitrogen backpressure regulator at 30 psi and adjusting the nitrogen flow rate to a constant value of

5.0 SCFH a reasonable rate of evaporation was established with no loss due to ebullition.

Using the abovementioned technique and periodically measuring the mass of the evaporation residue and cumulative evaporation time it was possible to establish mass percent evaporation loss as a function of cumulative evaporation time as shown in figure 12. By choosing as nearly as possible identical initial volumes of sample and maintaining identical rates of agitation and flow of nitrogen it was possible to use this function to predict the cumulative evaporation time required to obtain a desired residue.

Distillation

In both the Hempel and Engler distillations the technique employed was essentially that prescribed by the ASTM (4) with the exception that temperature readings were taken at the end of each cut, with the cuts varying in volume. A final boiling point of 425°F, at atmospheric pressure, was chosen arbitrarily.

A distillate collection technique was designed to facilitate the collection and examination of a number of small cuts and at the same time to minimize loss of distillate due to evaporation. This technique employed one dozen 25 milliliter graduated test tubes as distillate receivers for each distillation. These test tubes were placed in the receiver changing apparatus which, in turn, was filled with ice water before each distillation. During a distillation each receiver, as it was being filled, was raised so that the condenser funnel extended into the receiver and so minimized losses of distillate due to evaporation. At the end of each cut the receiver was stoppered and lowered into the

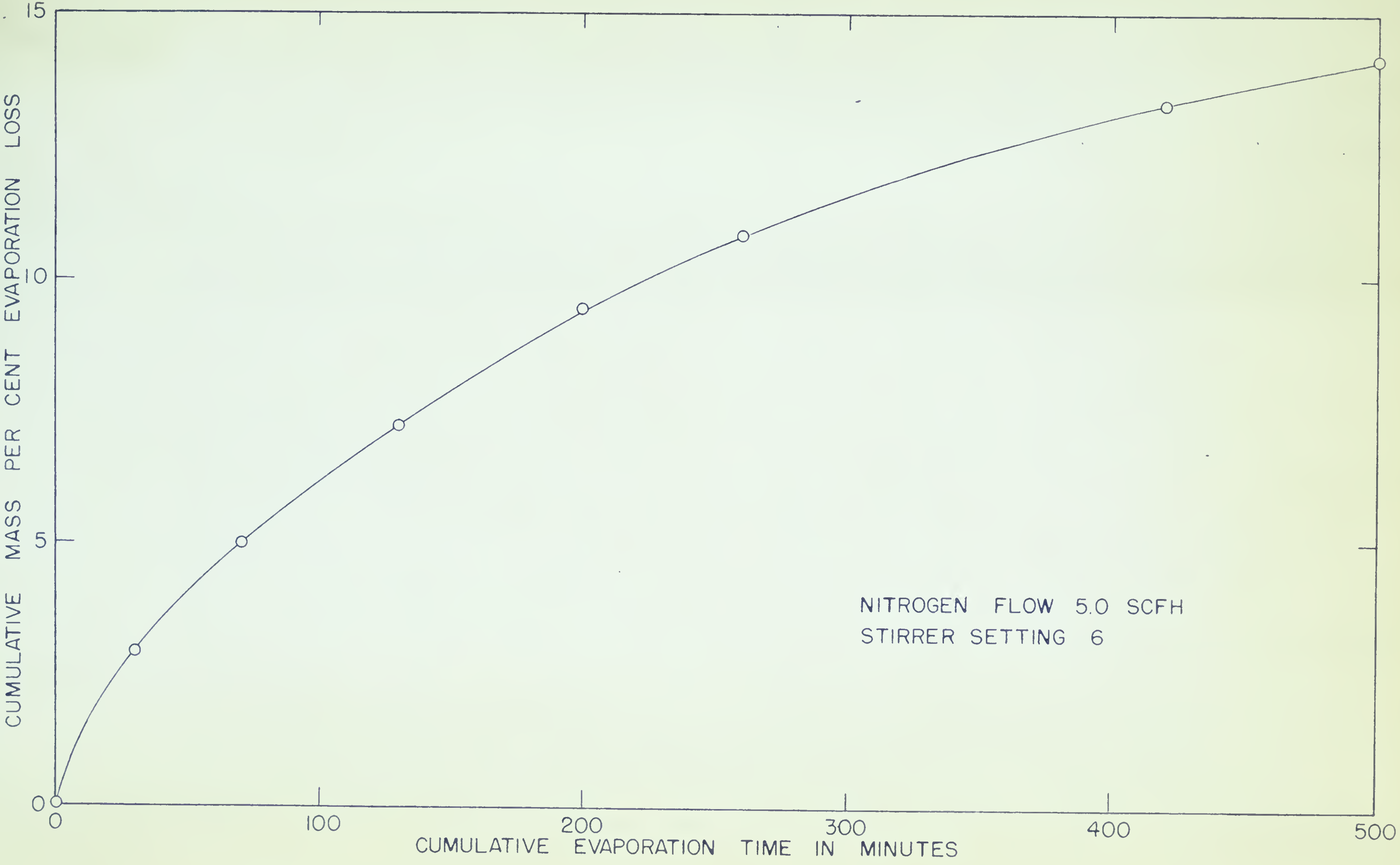

FIGURE 12 EVAPORATION APPARATUS CALIBRATION CURVE

ice water.

Since the volumes of the various cuts could only be read to two significant figures it was decided to calculate these volumes from a knowledge of their masses and specific gravities, both of which could be determined with greater accuracy. As a result, at the completion of each distillation, the stoppered receivers were dried with lintless tissue and their masses were determined.

Specific Gravity

Specific gravities of the crude oil, evaporation residues and distillation bottoms were determined by means of Gay-Lussac type specific gravity bottles. The bottles were filled to within one quarter inch of the top, tightly stoppered with cork stoppers and placed into a 60°F bath. When the samples reached 60°F the cork stoppers were replaced with the capillary glass stoppers. The glass stoppers were firmly seated and all excess oil was removed from the outside of the bottles. The bottles were then quickly transferred to an ice bath and chilled to cause a decrease in volume such that expansion during the weighing procedure would not cause a portion of the liquid to escape. After a short chilling period the bottles were removed from the bath and carefully wiped and their masses were determined.

Specific gravities of the distillate fractions were obtained subsequent to the determination of the mass of each cut. The technique consisted of filling the appropriate pipette pycnometer with sample at 60°F, removing excess sample from the surface of the pycnometer with lintless tissue and rapidly determining the mass of the pycnometer and contents by means of a direct reading analytical balance.

The sample and pycnometer were brought to 60°F by placing the pycnometer into the sample receiver which was in turn placed into the receiver changing apparatus. Water at 60°F was circulated through the apparatus until the sample attained a temperature of 60°F, at which time the pycnometer was filled by means of an aspirator bulb.

To minimize evaporation of distillate while it was being brought to 60°F the annular space between the receiver and the pycnometer was lightly stoppered with lintless tissue.

In all measurements of mass it was found necessary to handle all vessels with neoprene gloves so as to prevent errors due to the accumulation of moisture on the vessel surfaces as a result of handling. It was also necessary to minimize the time required to transfer vessels from constant temperature baths to the balance and perform the mass determination operations if the losses due to evaporation during these procedures were to remain small.

All specific gravity determination glassware was cleaned by rinsing first with benzene and then with pentane.

Sampling

All sampling techniques were designed so as to permit the obtaining of identical samples at such times as they were required. Although the designed techniques were successfully employed in the laboratory field techniques required modification.

In the original design of the field sampling technique it was proposed that the well from which the sample was to be obtained, be shut in prior to sampling, for a period equal to the shut in period before a production test. At the end of the shut in period the well was to

be produced at a very low rate, for a short time, so as to remove all those fluids which were in the wellbore during the shut in period. The well was then to be permitted to produce into the sample container, through the three-eighths inch opening, against a backpressure of approximately 5 psi.

Since at the time of sampling from Texaco Wizard Lake Crown C-2, the well had been producing for a number of days at approximately five times its normal rate it was not possible to employ the abovementioned sampling technique. To obtain a sample a portion of the production was diverted at the wellhead into the sample container via the three-eighths inch opening. A backpressure of 5 to 6 psi was maintained in the vessel by throttling the liberated gas by means of the one-eighth inch needle valve.

Natural gas to be used for displacement purposes was sampled at the separator. The sampling procedure consisted of first flushing the containers three times by pressuring to 65 psi and venting to atmosphere and then filling the containers to a final pressure of 70 psi.

Prior to the removal of a small volume of crude oil from the sample container the contents of the container were agitated to ensure that the portion removed was indeed representative of the whole. Because of the size of the container the agitation of the contents was accomplished by rolling the container about the laboratory floor for several minutes. Subsequent to agitation the required volume of sample was removed through the three-eighths inch angle valve while natural gas was being admitted into the sample container through the needle valve via the backpressure regulator.

To insure constant composition of the various aliquant portions removed, care had to be exercised to have the backpressure regulator set

at the same pressure as the pressure within the crude oil sample container. This practice prevented any gas solution or evolution during the displacement process.

The sampling of evaporation residues and distillation consisted of first mixing the liquid to be sampled, so as to ensure a representative sample, and then of removing the required volume by pouring. For example, to obtain a portion of an evaporation residue to be used as charge for a distillation the residue was agitated and a 300 milliliter portion of the residue was transferred to the distillation flask by means of a graduated cylinder. When the required portion of the residue was removed the flask was quickly stoppered and stored until such time as another sample of that residue was required.

All sampling and transferring of samples was conducted as quickly as possible so as to minimize losses due to evaporation during these procedures. For the same reason samples were exposed to atmosphere only when absolutely necessary and then for the shortest possible time.

V EXPERIMENTAL RESULTS

Refractive Index

In an attempt to verify, modify and expand Benkovskii's (5) method, crude oils from the Glenevis, Excelsior, Ellerslie, Redwater, Wizard Lake and Bellshill Lake Fields were examined. In all cases it was found impossible to determine the refractive index of either the crude oils or their residues.

Since all of the abovementioned crude oils are quite opaque, they and their residues had to be examined by means of the reflection technique. The results of the application of this technique were similar in all cases. Although sufficient contrast was observed between the light and dark fields at their extremities, there did not exist a sharp demarkation between the two fields, rather, one field gradually merged into the other.

The determination of the refractive indices of the various distillate fractions from these crude oils posed no problem by either the reflection or transmission technique. In fact the refractive indices of the distillate fractions from the Bellshill Lake crude oil were determined and found to be quite accurate and additive as stated by Benkovskii (5). These indices are not, however, presented in this report as they in themselves have little if any application.

Controlled Evaporation of Crude Oil from Texaco Wizard Lake Crown C-2*

Seven portions of crude oil from Texaco Wizard Lake Crown C-2 were subjected to controlled evaporation yielding the following residues;

---

* elsewhere referred to as TWLCC2.

Residue	Residue Yield Mass Percent	Volume Percent	API Gravity
Ha	98.59	98.10	34.62
G	97.04	96.13	33.89
B	95.07	93.75	33.12
C	93.37	91.75	32.55
D	92.12	90.30	32.16
E	91.14	89.17	31.86
F	91.16	88.99	31.49
A	85.84	83.27	30.44

When the residue yield data were plotted as a function of residue API gravity, smooth curves resulted, as may be seen from figure 13.

It may be observed that the data representing residue F do not fall on their respective curves. There is little doubt that this is due to an error in the counting of weights in the determination of the mass of residue F. When mass and volume percent residue yield, for residue F, are taken from the curves, the values 88.99 and 87.68 respectively, are obtained. These are taken to be the true values.

Distillation

As has been previously mentioned, both Engler type and Hempel type distillations were carried out on the crude oil and each of the residues. The data obtained indicate that as the degree of fractionation increases, the reliability of the data increases, their variation becomes less random and the slope of the distillation curves increases. This is well demonstrated by the distillation curves in figures 14 and 15.

Close scrutiny of the distillation curves indicates that the data are somewhat more scattered than is normal. This somewhat larger than normal variation was due, primarily, to the fact that temperature data were thought to be of secondary importance in this study and as a result were taken accordingly.

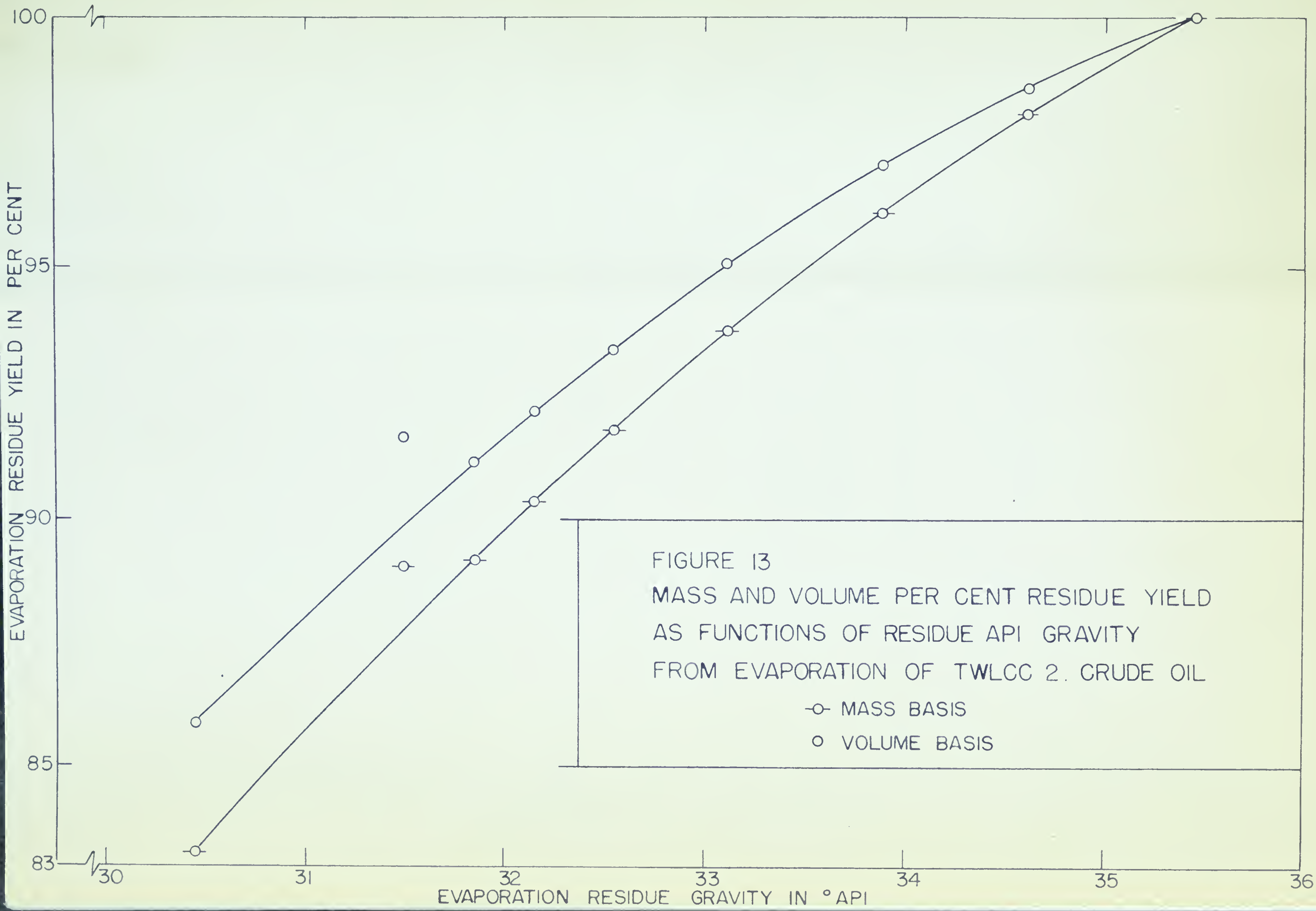

FIGURE 13
MASS AND VOLUME PER CENT RESIDUE YIELD
AS FUNCTIONS OF RESIDUE API GRAVITY
FROM EVAPORATION OF TWLCC 2. CRUDE OIL

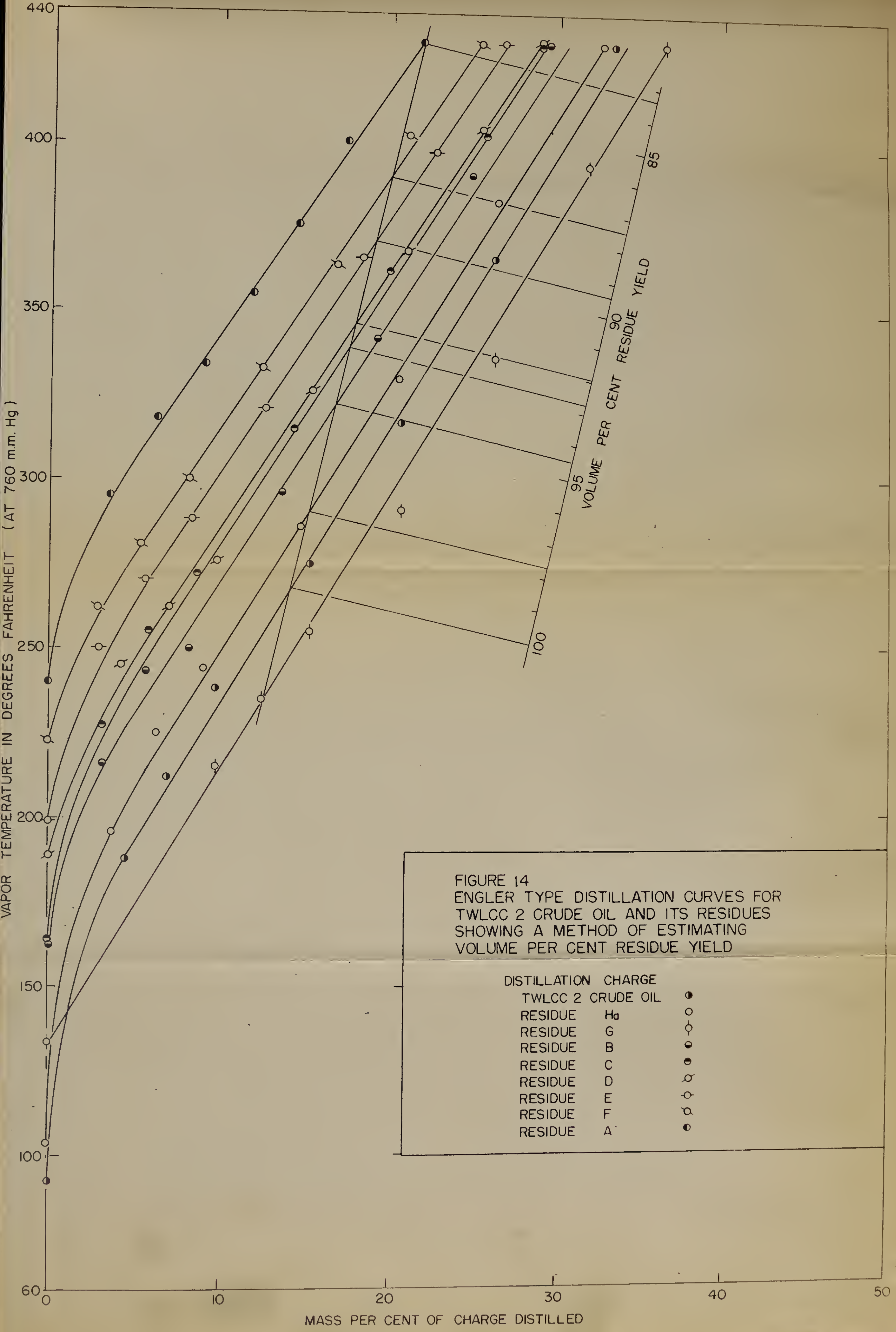

FIGURE 14
ENGLER TYPE DISTILLATION CURVES FOR TWLCC 2 CRUDE OIL AND ITS RESIDUES SHOWING A METHOD OF ESTIMATING VOLUME PER CENT RESIDUE YIELD

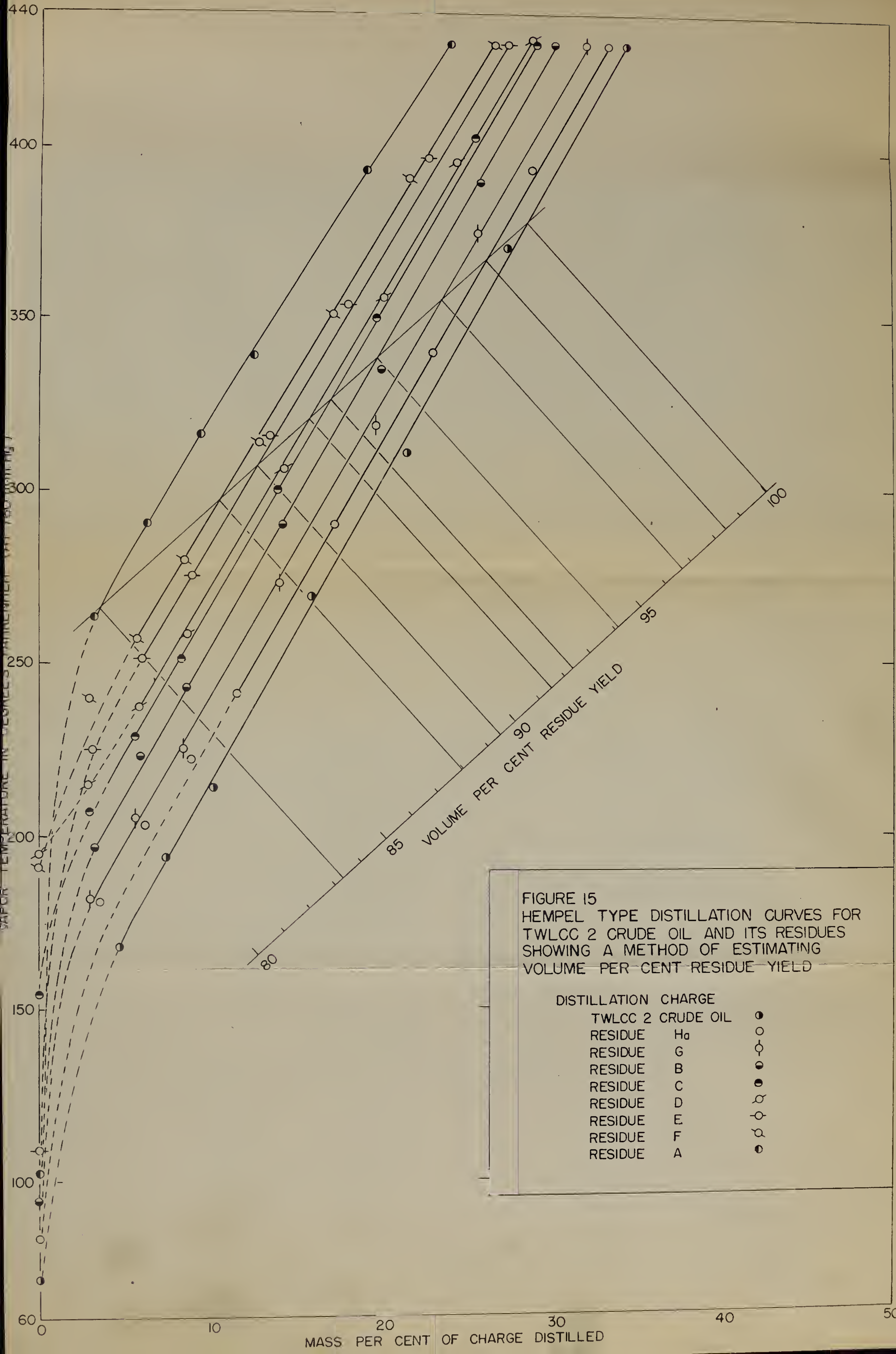

FIGURE 15
HEMPEL TYPE DISTILLATION CURVES FOR TWLCC 2 CRUDE OIL AND ITS RESIDUES SHOWING A METHOD OF ESTIMATING VOLUME PER CENT RESIDUE YIELD

Although distillation curves are seldom, if ever, plotted as best fit curves, the data in this study were plotted in this fashion. It is observed that for both methods of distillation the resulting curves are essentially straight, except in the vicinity of the initial boiling point. It may also be observed that the curves, for each distillation method, are quite parallel to one another. Furthermore the curves for the residues shift from the crude oil curve in the direction of decreasing percent distilled and increasing vapor temperature. The Engler type distillation curve on residue G represents the only departure from this general trend.

Mass percent distillation bottoms, upon distillation to a 431°F end point, were plotted versus mass percent evaporation residue yield for each distillation method. As may be seen from figures 16 and 17, fairly smooth correlations resulted. Although these correlations have no direct application to the estimation of losses due to evaporation, they demonstrate the previously mentioned observations concerning the effect of the degree of fractionation on the reliability and random variation of the distillation data obtained in this study. Figure 16 also indicates that the mass percent distillation bottoms for the Engler type distillation on residue G is much too low. This in turn indicates that either the mass of the charge or of the bottoms, for the distillation in question, is in error. It is quite immaterial which of these is in fact in error, since both affect the distillation curve in the same manner, namely, to shift all points, other than the initial boiling point, to the right, as may be observed in figure 14.

Ignoring the Engler type distillation curve on residue G, an examination of the remaining distillation curves indicates that the

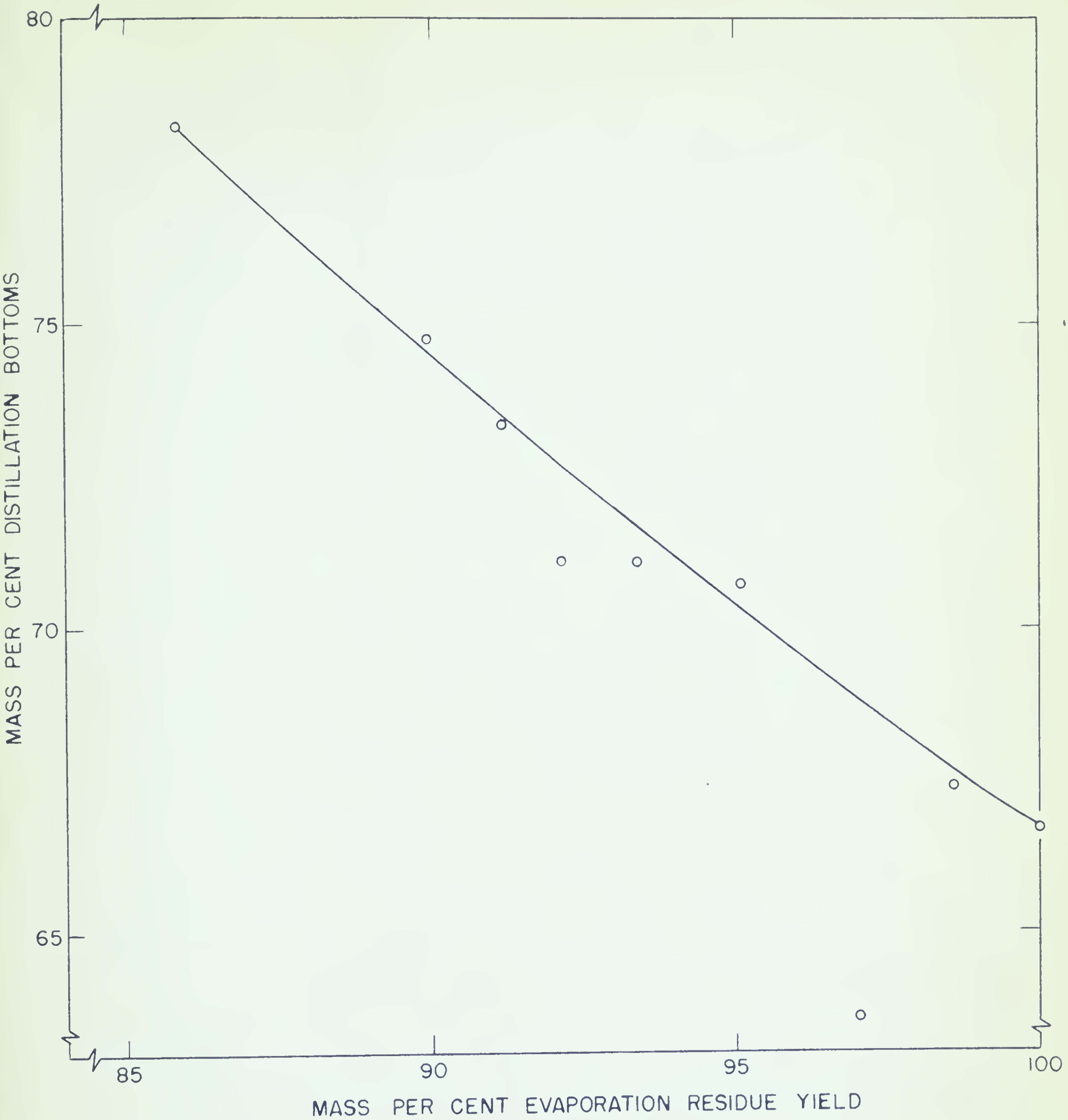

FIGURE 16
MASS PER CENT BOTTOMS UPON DISTILLATION TO 431 °F END POINT BY THE ENGLER TYPE METHOD AS A FUNCTION OF DISTILLATION CHARGE COMPOSITION.

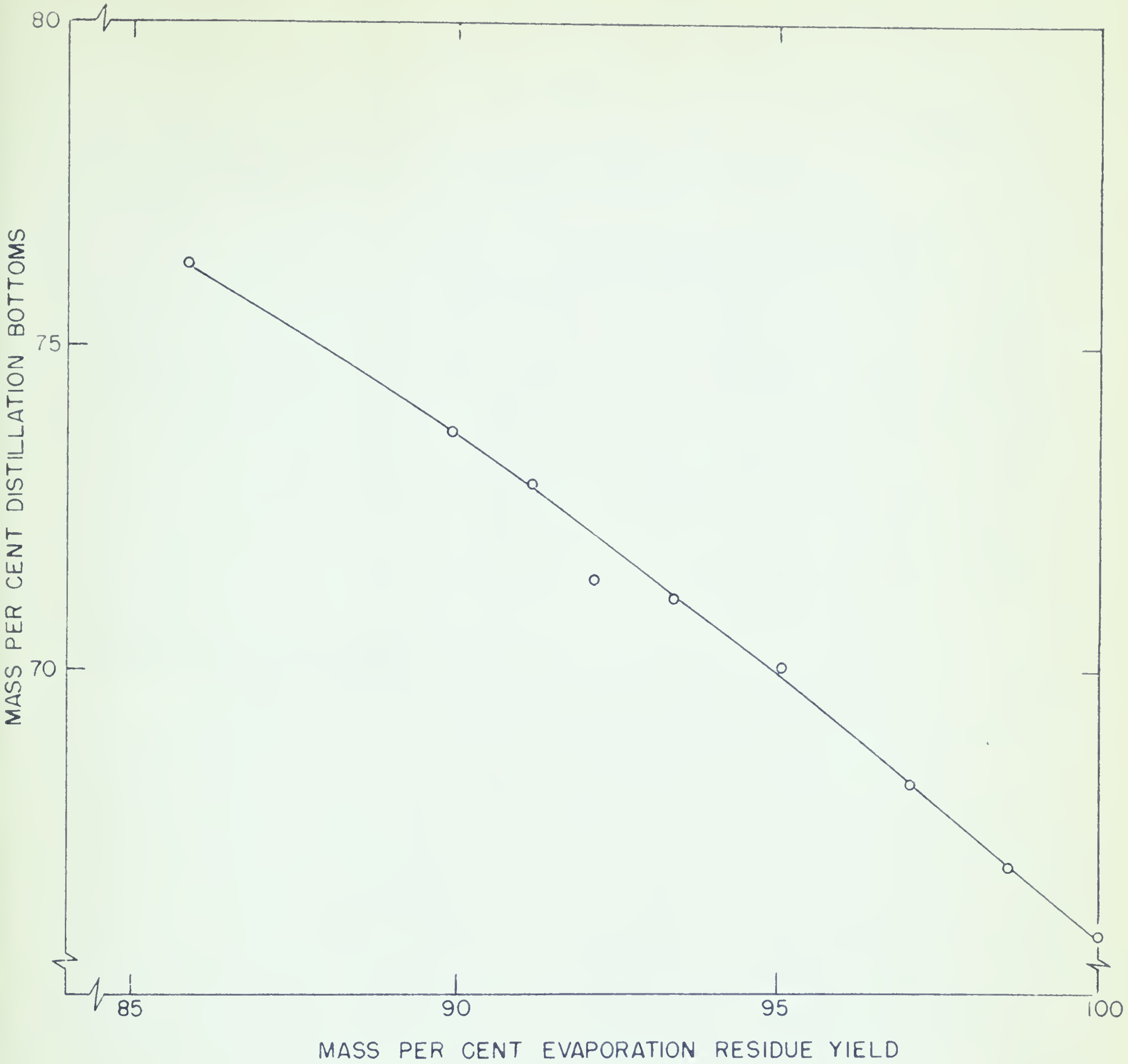

FIGURE 17
MASS PER CENT BOTTOMS UPON DISTILLATION TO 431 °F END POINT BY THE HEMPEL TYPE METHOD AS A FUNCTION OF DISTILLATION CHARGE COMPOSITION.

residue curves shift from the crude oil curve inversely as the percent residue yield. In fact, the separation between the residue and crude oil curves may be used to estimate the percent residue yield represented by the residues. Such estimations were made, using the constructions in figures 14 and 15 and yielded the following results;

	Volume Percent Residue Yield		
	Measured	Estimated	
Charge		Engler	Hempel
TWLCC2 Crude Oil	100.00	100.00	100.00
Residue Ha	98.10	97.65	98.30
G	96.13		96.42
B	93.75	94.90	94.07
C	91.75	92.67	92.27
D	90.30	91.90	91.40
E	89.17	89.35	89.40
F	87.68	87.35	87.95
A	83.27	83.27	83.27

Examination of Distillate Fractions

To show the variation of API gravity from drop to drop for the various distillations, API gravity mid percent curves were plotted, for each distillation method, as shown in figures 18 and 19. These curves were plotted on a mass basis since it is only on this basis that API gravity is additive. One further peculiarity of these curves lies in the fact that the uncollected portion of distillate, commonly referred to as distillation loss, is in this case, considered to comprise a fraction of lower API gravity than that of the first collected fraction. This has the effect of shifting each curve to the right a distance equal to the distillation loss.

It is evident from figures 18 and 19 that increasing fractionation affects the data and the curves in much the same fashion as it does the distillation curves. The API gravity data exhibit much more scattering

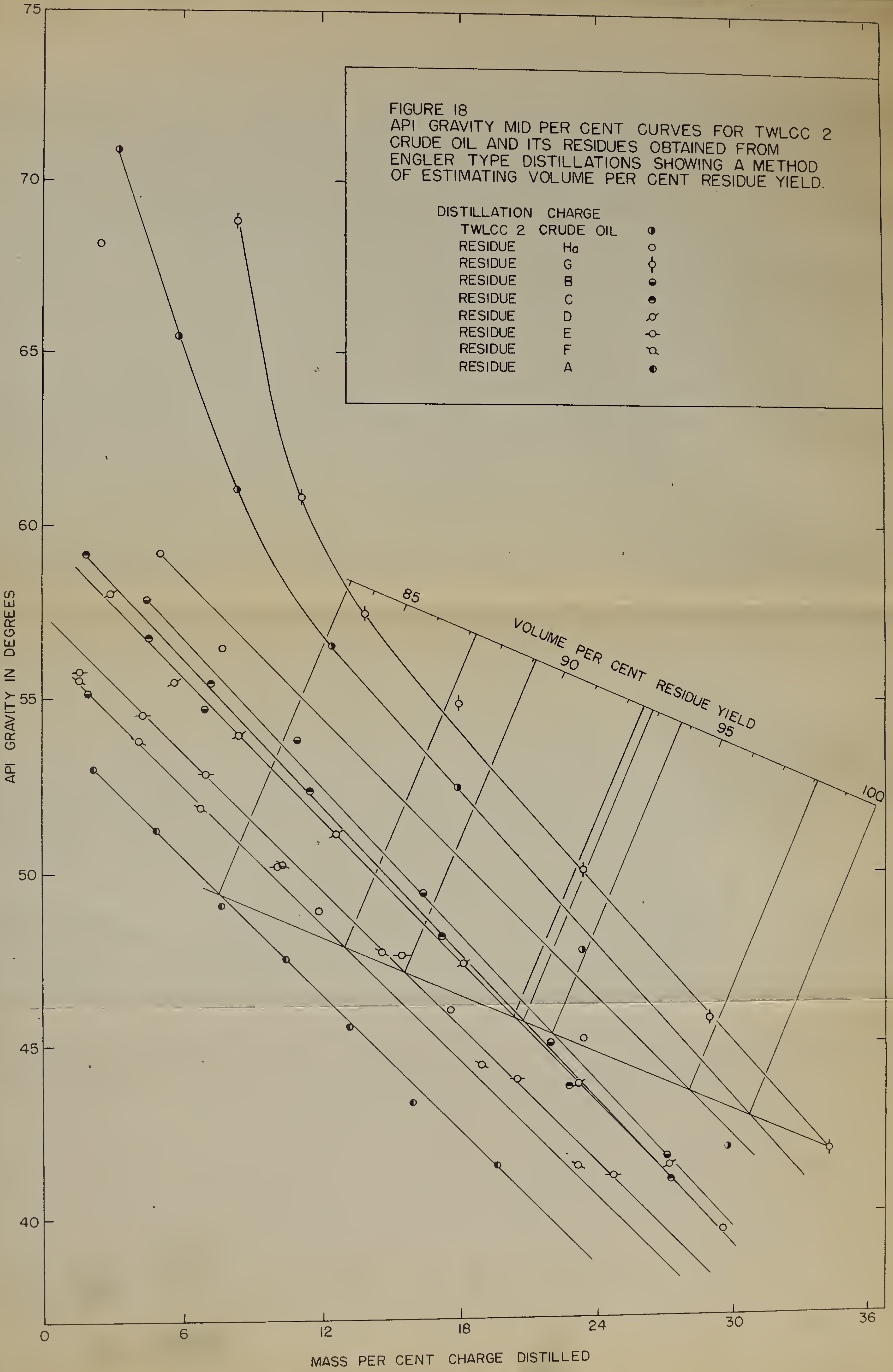

FIGURE 18
API GRAVITY MID PER CENT CURVES FOR TWLCC 2 CRUDE OIL AND ITS RESIDUES OBTAINED FROM ENGLER TYPE DISTILLATIONS SHOWING A METHOD OF ESTIMATING VOLUME PER CENT RESIDUE YIELD.

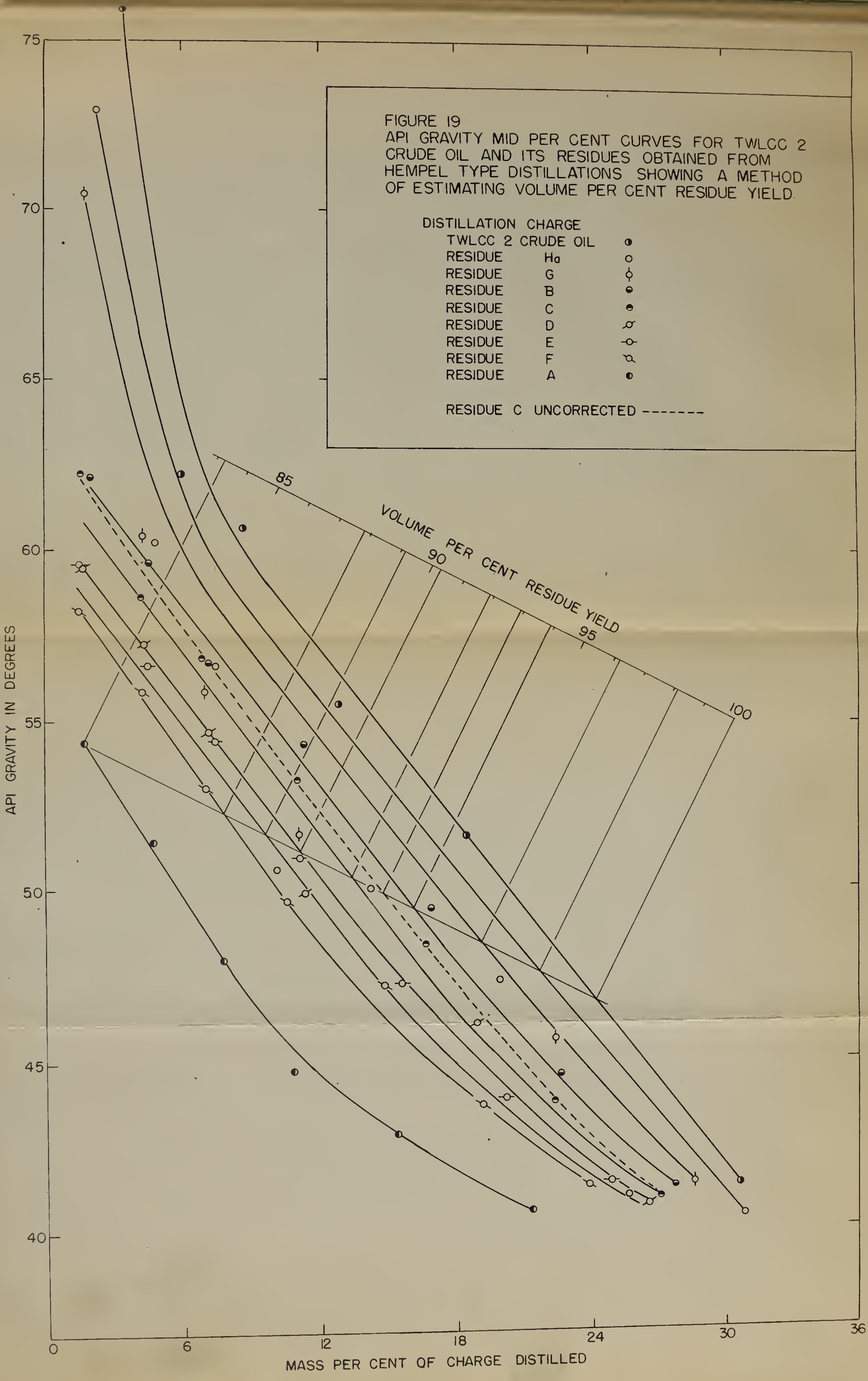

FIGURE 19
API GRAVITY MID PER CENT CURVES FOR TWLCC 2 CRUDE OIL AND ITS RESIDUES OBTAINED FROM HEMPEL TYPE DISTILLATIONS SHOWING A METHOD OF ESTIMATING VOLUME PER CENT RESIDUE YIELD.

than do the distillation data, indicating that the accuracy of the data is not nearly as great as was expected from the precision of measurement employed. The greater scattering in figure 18, as compared to figure 19, suggests that the effect of the degree of fractionation on the gravity data, although similiar, is more pronounced that it is in the case of the distillation data.

Despite the scattered nature of the data, best fit curves were drawn for each method of distillation. It may be seen that the curves for both methods are similar in that they tend to be concave upwards at either end, essentially linear in the middle and parallel to one another. It is true that the upward concavity is not well demonstrated by the Engler type curves and rather poorly demonstrated by Hempel type curves in the region of high API gravity, but the parallel nature of the middle, essentially linear, portion is fairly well developed in both cases. This portion of the curves was examined and it was observed that as in the case of the distillation curves the API gravity mid percent curves, for the residues, shift away from the crude oil curve. In this instance the shift is in the direction of decreased percent distilled and decreased API gravity. As may be expected the shift varies inversely as percent residue yield. The separation between the residue and crude oil curves may again be used to estimate the volume percent residue yield represented by the residues. Such estimations were made for both distillation methods by means of the construction shown in figures 18 and 19. The following results were obtained;

	Volume Percent Residue Yield		
	Measured	Estimated	
Charge		Engler	Hempel
TWLCC2 Crude Oil	100.00	100.00	100.00
Residue Ha	98.10	98.10	98.10
G	96.13		96.16
B	93.75	93.70	93.90
C	91.75	92.75	91.90
D	90.30	92.50	90.27
E	89.17	88.10	89.10
F	87.68	87.20	87.77
A	83.27	83.27	83.27

The Engler type curve on residue G was disregarded for previously mentioned reasons.

Since it was felt that the observations made to this point had fairly well established the effects of the degree of fractionation, further observations concern themselves only with data obtained from the Hempel type distillation since these data are the more accurate.

Using corrected values of API gravity of each fraction, obtained from figure 19, their masses along with the API gravities and masses of the distillation bottoms, the yields of various bottoms and their API gravities were calculated for each Hempel type distillation by means of the following equation;

$$\text{API ave.} = \frac{\sum_{1}^{n} \text{APIi} \cdot \text{Wi}^{*}}{\sum_{1}^{n} \text{Wi}} \qquad (11)$$

* Wi = mass of ith fraction.

These calculated data were plotted as API gravity distillation bottoms yield curves (17), shown in figure 20.

An examination of figure 20 indicates that the API gravity distillation bottoms yield curves for the Hempel type method are essentially straight at low yields but develop upward concavity at high yields. The curves are nearly parallel to one another. The residue curves, as may be expected, shift from the crude oil curve in the direction of increased yield and decreased gravity. The shift again varies inversely as the residue yield. The separation between the crude oil curve and the residue curves may be used to estimate the volume percent residue yield represented by the residue. Such an estimation, as shown by the construction in figure 20, yields the following results;

	Volume Percent Residue Yield	
Charge	Measured	Estimated
TWLCC2 Crude Oil	100.00	100.00
Residue Ha	98.10	98.60
G	96.13	97.18
B	93.75	94.20
C	91.75	91.88
D	90.30	90.15
E	89.17	89.30
F	87.68	87.80
A	83.27	83.27

It must, however, be observed that this estimation is best made in the region of high bottoms yield. This is somewhat unfortunate since the exact nature of the curves in this region, with the exception of the 100 percent points, is not well established, because of the uncertainty of the API gravity of the light fractions,indicated in figure 19.

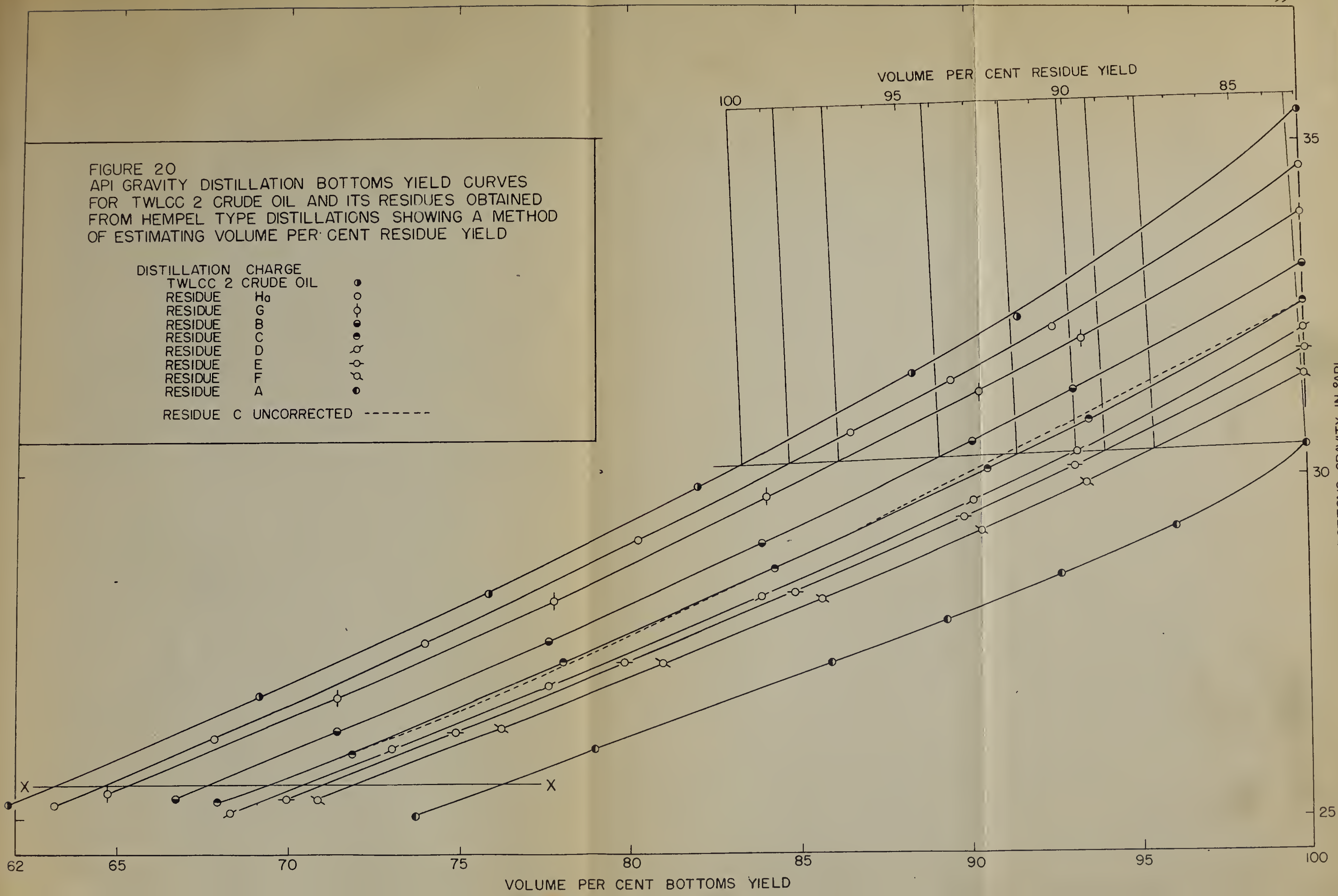

FIGURE 20
API GRAVITY DISTILLATION BOTTOMS YIELD CURVES FOR TWLCC 2 CRUDE OIL AND ITS RESIDUES OBTAINED FROM HEMPEL TYPE DISTILLATIONS SHOWING A METHOD OF ESTIMATING VOLUME PER CENT RESIDUE YIELD

An examination of the API gravity distillation bottoms yield curves in the region of low bottoms yield indicates that, had the distillations been terminated in such a fashion that, the API gravity of the bottoms was in each case 25.50 degrees, rather than at a vapor temperature of 431°F then the volume percent bottoms yield for each distillation would have been as follows;

Charge	Volume Percent Bottoms
TWLCC2 Crude Oil	63.15
Residue Ha	64.64
G	65.35
B	67.70
C	69.50
D	70.45
E	71.05
F	71.95
A	76.20

Now, if the distillation is such that distillation bottoms of equal API gravity are in fact of identical composition, then it is obvious that the volume percent bottoms of the crude oil when divided by the volume percent bottoms of a residue will equal the volume percent residue yield represented by the residue. This method of calculation was applied to this case with the following results;

	Volume Percent Residue Yield	
Charge	Measured	Calculated
TWLCC2 Crude Oil	100.00	100.00
Residue Ha	98.10	97.69
G	96.13	96.63
B	93.75	93.28
C	91.75	90.86
D	90.30	89.64
E	89.17	88.88
F	87.68	87.77
A	83.27	82.87

This method, unlike that employing curve separation, is not too concerned with the light fractions since its accuracy is primarily dependant upon observation made on the distillation bottoms, and the last fraction.

VI DISCUSSION AND CONCLUSIONS

As has been mentioned elsewhere in this work, it was not possible to employ the designed technique to obtain the field crude oil sample. It is questionable whether the procedure employed could be repeated and an identical sample obtained. Furthermore, due to the nature of the container and the manner in which the sample was obtained, extensive stripping action occurred within the container. This resulted in the sample having an API gravity of 35.45 degrees, some 3 degrees lower than that of the lease stock tank oil. From these facts it must be concluded that although the sampling technique and container were adequate for the purpose of this study, they are wholly inadequate for any other purpose.

It was observed that errors of approximately 10 and 20 grams were incurred in the measurement of mass, in evaporation run F and the Engler type distillation on residue G respectively. These errors were no doubt, due to the necessity of counting the large numbers of weights used when determining large masses on a double pan balance. Although errors of this type are inexcusable, it must be observed that, since the use of a double pan balance is very time consuming, the use of a direct reading balance would serve to eliminate counting errors as well as to decrease errors due to evaporation during the mass determination period.

An examination of the distillation curves shows that, although the Engler type data are in general more scattered than are the Hempel type, the Engler type initial boiling points are much more reliable than are those obtained by the Hempel method. This,of course,is due to the presence of the fractionating column in the Hempel method. Because of the fact that reliability shifts from one region of these curves to another,

there is little choice between the two methods for the purpose of evaporation loss estimation.

Increased care in the determination of vapor temperatures would, no doubt, increase the accuracy of the distillation curves and would most likely indicate the Hempel curves to be slightly superior to the Engler curves for evaporation loss estimation purposes. It is, however, a well known fact that even with extreme care the order of accuracy which can be obtained in the determination of vapor temperatures is comparatively low. For this reason the use of distillation curve separations for the estimation of evaporation losses is not recommended.

The adoption of capillary type pycnometers for the determination of gravities of distillate fractions, was based on the misconception that, since the high API gravity fractions were the ones lost as a result of evaporation they were the ones to be examined with the greatest care. A perusal of the gravity data indicates that, although the use of these pycnometers enables one to determine gravities with great precision, the accuracy of the gravities so determined, isn't very high. This is understandable when it is realized that this method involves the determination of small differences by the measurement of large masses. Although the accuracy of this method could be increased by increasing the pycnometer volumes and preparing the capillary tips with greater care, it is suggested that their use in such investigations be discontinued and a bouyancy technique be adopted.

From an examination of the API gravity mid percent curves in figure 19 it is quite obvious that, although the true nature of several curves is fairly well defined, there remains a certain amount of uncertainty concerning the others. It is true that the several well defined curves

may serve to determine the shape of the remaining curves but, if the curves for residue C and the residue C uncorrected, of figure 19, are examined it is obvious that because of the scattered nature of the data, the exact position of a curve may be in question. Though in this particular case, the curve for residue C seems the most logical, this is only true because it is contiguous to two other curves of very similar shape. It may be held that the shift between these curves is small, nevertheless the difference in the estimation of evaporation loss by the two curves is of the order of 12.5 percent of the actual loss.

An examination of figure 18 indicates that, due to the scattered nature of the data, the shapes and positions of the curves are even more in doubt than is the case in figure 19.

When the distillation and API gravity mid percent curves are examined together it is obvious that they have many points in common. In both cases accurate data are difficult to obtain. If accurate estimations of evaporation losses are to be made using such curves large amounts of data are necessary. The shape of these curves, although essentially linear in this case, is a function of the composition of the crude oil and its residues. It must be recognized that in such cases where these curves are not linear evaporation loss estimations, employing curve separations, will be more difficult and less reliable.

From these observations it must be concluded that the use of the curve separations technique on distillation and mid percent curves, for the purpose of evaporation loss estimation, is unadvisable. If, however, such methods must be used, the most accurate results will be realized by

using API gravity mid percent curves obtained by means of a distillation method with a high degree of fractionation.

Admittedly the curve separation technique when applied to yield curves suffers from difficulties which are identical to those encountered when this technique is applied to mid percent curves, but the effect of these difficulties on yield curves is much less pronounced. This is well demonstrated by the curves for residue C and residue C uncorrected in figures 19 and 20. Since variations in the data obtained on the various fractions are dampened in the construction of yield curves, it must be concluded that the application of the curve separation technique to yield curves is preferrable to its application to mid percent curves. Both methods require a large amount of data if accurate results are to be realized.

The accuracy of the estimation technique which employs calculations involving volume percent bottoms yields is dependant upon the accuracy of the data obtained and the assumption that distillation bottoms of equal API gravity are in fact of identical composition. Since it is possible to obtain accurate data on distillation bottoms, the heavier distillate fractions and the original charge, the only real difficulty with this method rests with the assumption involved. It is obvious that as the degree of fractionation increases and the bottoms API gravity decreases the validity of the assumption increases.

An examination of the abovementioned observations leads to the conclusion that the calculation of evaporation loss using volume percent yield data is in fact superior to all methods of evaporation loss estimation by means of curve separation techniques. It is more than likely that,

with a proper choice of equipment and technique, the suggested calculation method may fulfill the needs of the petroleum producer.

VII RECOMMENDATIONS

Since an accurate evaporation loss estimation technique could prove valuable not only in the design of production practices but for the purpose of more accurately convering production data to reservoir conditions it is recommended that;

(1) the estimation by calculation technique herein described be examined in more detail.

(2) for future investigation the reference sample be a reservoir sample of the crude oil brought to 60°F and atmospheric pressure by differential liberation.

(3) a distillation technique with a degree of fractionation equal to or higher than that of the Hempel type be used.

(4) the distillations be conducted in such a manner that sufficiently large volumes of distillate be obtained to permit the use of a bouyancy technique for gravity determination purposes.

(5) direct reading balances be used for mass determinations.

(6) the use of distillation end point temperatures in the vicinity of the cracking point be considered.

(7) the effect of the method of evaporation on the estimation accuracy be investigated.

BIBLIOGRAPHY

1. API, "Evaporation Loss From Storage Tanks", API Proc., v. 32, sec. 1, p. 213, 1952.

2. API, "Tentative Methods of Measuring Evaporation Loss from Petroleum Tanks and Transporation Equipment", API Bull. 2512, 1957.

3. Ashley, C. C., "Evaporation Losses of Petroleum Oils from Steel Tanks", O. and G. J., p. 170, Nov. 18, 1938.

4. ASTM, "Tentative Method of Test for Distillation of Crude Petroleum", ASTM Standards, D285-5T, 1954.

5. Benkovskii, V. G., "Refractometric Determination of Losses of Petroleum Due to Evaporation", Neftyanoe Khoz 26, 7, 1948.

6. Bignell, L. G. E., "Evaporation and Corrosion Practically Eliminated in Oil Field Pipe Line Gathering Equipment", O. and G. J., p. 13, April 19, 1934.

7. Bignell, L. G. E., "Vapor Gathering Systems With Steel Balloons Reduce Evaporation and Corrosion Losses", O. and G. J., p. 8, Oct. 12, 1933.

8. Bassler, R. B., "Forecasting Evaporation Losses", O. and G. J., p. 63, Aug. 10, 1939.

9. Chenicek, G.W. and Whitman, W.G., "Determination of Evaporation Losses", API Proc., Ref. Bull., Dec., 1930.

10. D'Aragon, H. J., "Economic Prevention of Evaporation Losses", Pet. Eng. p. 179, March 1945.

11. Griswold, "Fuels Combustion and Furnaces", McGraw-Hill, 1946.

12. Hill, R. W., "The Lease-Storage-Tank Evaporation-Loss Problem", API Proc., v. 32, sec. 1, p. 277, 1952.

13. Huntington, R. L., "Application of Unit Operations to Fractionation and Other Vaporization Processes", Pet. Ref., 23: 111-13, June, 1944.

14. Huntington, R. L., "Economics of Reducing Crude Oil Vaporization Losses", O. and G. J., p. 108, June 15, 1950.

15. Kallam, F. L., "Stabilization of Crude Oil, Chronological Account of, From 1926 to Present", Pet. Ref. 22: 93-101F; 91-6M, 1943.

16. Mauney, S.F. and Vandaveer, G.M., "Conservation of Gravity in the Production of Oil", O. and G. J., p. 74, May 26, 1938.

17. Nelson, "Petroleum Refinery Engineering", McGraw-Hill, 3rd Ed. 1949.

18. Nelson, W. L., "References on Evaporation Losses in Storage", O. and G. J., p. 95, Dec. 20, 1947.

19. O. and G. J., "Oil Losses - Elimination and Control", O. and G. J., p. 260, July 28, 1949.

20. O. and G. J., "Over 41 Million Barrels of Oil Saved Annually by Reducing Evaporation", O. and G. J., p. 20, Dec. 19, 1935.

21. O. and G. J., "Profits by Gravity Control", O. and G. J., p. 227, Dec. 30, 1943.

22. Schmidt, L., "Applied Methods and Equipment for Reducing Evaporation Losses of Petroleum and Gasoline", USBM Bull. 379, 1934.

23. Smith, N.A.C., Smith, H.M., Black, O.C., and Garton, E.L., "The Bureau of Mines Routine Method for the Analysis of Crude Petroleum", USBM Bull. 490, 1951.

24. Stauffer, J.C., Roberts, J.K., and Whitman, W.G., "Determination of the Vapor Pressure of Naphthas", Ind. and Eng. Chem., Anal. Ed., vol. 1-2, p. 88, Jan. 15, 1930.

25. Tucker, M., "Stabilization of Crude Oil in the Field Comes Into General Use", O. and G. J., p. 60, June 24, 1937.

26. Viles, P.S., and Jones, C.T., "Estimating Oil Losses by Atmospheric Evaporation from Refinery Separator Surfaces", Pet. Ref., 31; 117-19, Jan., 1952.

27. Wiggins, J. H., "Evaporation Loss of Petroleum in the Mid-Continent Field", USBM Bull. 200, 1922.

28. Williams, N., "Portable Pressure Gravity Test Unit Checks Evaporation Losses", O. and G. J., p. 43, May 13, 1943.

APPENDIX

TABLE I

PYCNOMETER CALIBRATION

MASS OF PYCNOMETER IN GRAMS

Pycnometer Trial	A	B	C	D	E	F	H	J	K
1	13.2898	12.2237	14.0033	15.0670	15.0699	14.3179	14.6170	12.9503	13.5339
2	13.2901	12.2235	14.0034	15.0672	15.0700	14.3180	14.6170	12.9503	13.5339
3	13.2900	12.2234	14.0033	15.0673	15.0700	14.3179	14.6170	12.9503	13.5339
Average	13.2900	12.2235	14.0033	15.0672	15.0700	14.3179	14.6170	12.9503	13.5339

MASS OF PYCNOMETER FILLED WITH DISTILLED WATER At 60°F in Grams

Pycnometer Trial	A	B	C	D	E	F	H	J	K
1	17.0033	14.7557	17.5605*	17.8922*	17.2451	16.6230	17.9082*	15.9804	16.3226
2	17.0063*	14.7565	17.5609	17.8940	17.2459	16.6266*	17.9072	15.9810	16.3231
3	17.0034	14.7574*	17.5610	17.8928*	17.2460	16.6269*	17.9068	15.9825*	16.3227
4	17.0029	14.7563	17.5603*	17.8936	17.2451	16.6226	17.9073	15.9819*	16.3205*
5	17.0036	14.7572*	17.5612	17.8935	17.2451	16.6224	17.9075	15.9814	16.3222
6	17.0035	14.7563	17.5614	17.8930	17.2457	16.6228	17.9078	15.9806	16.3222
7	17.0035	14.7562	17.5612	17.8934	17.2459	16.6226	17.9075	15.9805	16.3225
8	17.0032	14.7560	17.5610	17.8936	17.2456	16.6230	17.9065*	15.9810	16.3216*
9	17.0030	14.7559	17.5613	17.8935	17.2453	16.6225	17.9075	15.9808	16.3224
10	17.0038	14.7565	17.5615	17.8937	17.2456	16.6231	17.9075	15.9812	16.3226
Average	17.0034	14.7562	17.5611	17.8935	17.2455	16.6228	17.9074	15.9809	16.3225
Mass of Pyc.	13.2900	12.2235	14.0033	15.0672	15.0700	14.3179	14.6170	12.9503	13.5339
Mass of Water	3.7134	2.5327	3.5578	2.8263	2.1755	2.3049	3.2904	3.0306	2.7886

* Omitted from average

TABLE II

MASSES OF RECEIVERS, STOPPERS AND HANGER

IN GRAMS

Receiver \ Trial	1	2	3	Average
1W	25.7191	25.7191	25.7191	25.7191
2W	26.3216	26.3214	26.3214	26.3215
3W	25.7078	25.7077	25.7076	25.7077
4W	26.9040	26.9040	26.9040	26.9040
5W	24.8535	24.8537	24.8536	24.8536
6W	25.2972	25.2972	25.2972	25.2972
7W	25.3757	25.3758	25.3757	25.3757
8W	25.4410	25.4411	25.4410	25.4410
9W	24.5708	24.5707	24.5706	24.5707
10W	23.7775	23.7775	23.7774	23.7775
11W	24.7460	24.7459	24.7459	24.7459
12W	24.7812	24.7813	24.7812	24.7812
2B	27.7437	27.7437	24.7438	24.7437
3B	27.3972	27.3972	27.3972	27.3972
4B	27.5957	27.5957	27.5957	27.5957
5B	29.1287	29.1287	29.1287	29.1287
6B	29.0648	29.0649	29.0649	29.0649
7B	29.0833	29.0833	29.0833	29.0833
8B	27.7933	27.7934	27.7933	27.7933
9B	29.1558	29.1558	29.1558	29.1558
10B	28.2668	28.2669	28.2669	28.2669
11B	28.8103	28.8103	28.8103	28.8103

Stopper	Average
1	1.2130
2	1.5819
3	1.1642
4	1.6466
5	1.3060
6	1.4557
7	1.1241
8	1.2438
9	1.4066
10	1.4768
11	1.6079
12	1.1435
13	1.4346
14	1.2368
15	1.4877
16	1.1225
17	1.2042
18	1.3982
19	1.4420
20	1.1086
21	1.2982
22	1.1270
23	1.4274

Trial	Hanger
1	3.1419
2	3.1420
3	3.1420
4	3.1420
5	3.1420
Average	3.1420

TABLE III

GRAVITY DETERMINATIONS ON TWLCC2* CRUDE OIL

SPECIFIC GRAVITY BOTTLE DATA[α]

Bottle	2	3	4	5
Mass of Bottle Filled With Water at 60°F (gms)	39.0277	38.8817	66.8672	65.5448
Mass of Bottle (gms)	13.8728	13.9988	16.7730	16.3840
Mass of Water (gms)	25.1549	24.8829	50.0942	49.1608

CRUDE OIL GRAVITY DATA

Trial	1	2	3
Bottle	5	5	4
Mass of Bottle + Oil at 60°F (gms)	58.0500	58.0481	59.2305
Mass of Bottle (gms)	16.3840	16.3840	16.7730
Mass of Oil at 60°F (gms)	41.6660	41.6641	42.4575
M.E.V.W.[β] at 60°F (gms)	49.1608	49.1608	50.0942
SG 60°F/60°F	0.84755	0.84751	0.84755
API Gravity (°)	35.45	35.46	35.45
Average SG 60°F/60°F		0.84754	
Average Density at 60°F (gms/ml)		0.84673	
Average API Gravity (°)		35.45	

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* Texaco Wizard Lake Crown C-2

[α] Courtesy Oil and Gas Conservation Board Laboratory

[β] Mass of an Equal Volume of Distilled Water

TABLE IV

CALIBRATION OF EVAPORATION APPARATUS

RUN A ON TWLCC2 CRUDE OIL

	Crude Oil	Final Evaporation Residue
Mass of Flask + Sample (gms)	1046.52	951.55
Mass of Flask (gms)	375.62	375.62
Mass of Sample (gms)	670.90	575.93
Density of Sample at 60°F (gms/ml)	0.84673	0.87292
Volume of Sample at 60°F (mls)	792.34	659.77
Volume Percent Residue (%)		83.27
Volume Percent Loss (%)		16.73

	Time	Evaporation Time (mins)	Cumulative Evaporation Time (mins)	Mass (gms)	Evaporation Loss (gms)	Mass Percent Loss %	Cumulative Mass Percent Loss %	Nitrogen Flow Rate (SCFH)
Start	11:04 AM	0	0	1046.52	0	0	0	5.0
Stop	11:34	30	30	1027.05	19.47	2.90	2.90	5.0
Start	11:39			1027.05				5.0
Stop	12:19 PM	40	70	1013.19	13.86	2.07	4.97	5.0
Start	12:25			1013.19				5.0
Stop	1:25	60	130	998.10	15.09	2.25	7.22	5.0
Start	1:30			998.10				5.0
Stop	2:40	70	200	982.90	15.20	2.26	9.48	5.0
Start	2:45			982.90				5.0
Stop	3:45	60	260	973.93	8.97	1.34	10.82	5.0
Start	3:50			973.93				5.0
Stop	6:30	160	420	957.46	16.47	2.45	13.27	5.0
Start	6:35			957.46				5.0
Stop	7:55	80	500	951.55	5.91	0.88	14.16	5.0

TABLE IV (Continued)

GRAVITY OF FINAL RESIDUE

Bottle	5
Mass of Bottle + Sample at 60°F (gms)	59.3389
Mass of Bottle (gms)	16.3840
Mass of Sample at 60°F (gms)	42.9549
M.E.V.W. at 60°F (gms)	49.1608
SG 60°F/60°F	0.87376
Density of Sample at 60°F (gms/ml)	0.87292
API Gravity (°)	30.44

TABLE V

EVAPORATION DATA ON TWLCC2 CRUDE OIL

(Stirrer Setting 6.0; Nitrogen Flow Rate 5.0 CFH.)

Run	Ha	G	B	C
Mass of Flask + Crude Oil (gms)	1132.70	1134.32	1119.25	1129.45
Mass of Flask (gms)	376.15	375.67	371.15	375.72
Mass of Crude Oil (gms)	756.55	758.65	748.10	753.73
Density of Crude Oil at 60°F (gms/ml)	0.84673	0.84673	0.84673	0.84673
Volume of Crude Oil (mls)	893.50	895.98	883.52	890.17
Start Evaporation	1:19	1:36	2:07	12:21
Stop Evaporation	1:31	2:16	3:27	2:31
Evaporation Time (mins)	12	40	80	130
Mass of Flask + Residue (gms)	1122.05	1111.84	1082.40	1079.50
Mass of Flask (gms)	376.15	375.67	371.15	375.72
Mass of Residue (gms)	745.90	736.17	711.25	703.78

GRAVITY DETERMINATIONS ON EVAPORATION RESIDUES

Bottle	2	3	2	3	4	5	4	5
Mass of Bottle + Sample at 60°F (gms)	35.2992	35.1942	35.3949	35.2877	59.8294	58.6405	59.9791	58.7865
Mass of Bottle	13.8728	13.9988	13.8728	13.9988	16.7730	16.3840	16.7730	16.3840
Mass of Sample at 60°F (gms)	21.4264	21.1954	21.5221	21.2889	43.0564	42.2565	43.2061	42.4025
M.E.V.W. at 60°F (gms)	25.1549	24.8829	25.1549	24.8829	50.0942	49.1608	50.0942	49.1608
SG 60°F/60°F	0.85178	0.85181	0.85558	0.85556	0.85951	0.85956	0.86250	0.86253
Density of Sample at 60°F (gms/ml)	0.85096	0.85099	0.85476	0.85474	0.85869	0.85875	0.86167	0.86170

TABLE V (Continued)

Run	Ha	G	B	C
Average Density at 60°F (gms/ml)	0.85097	0.85475	0.85872	0.86169
Average SG 60°F/60°F	0.85179	0.85557	0.85954	0.86252
Average API Gravity (°)	34.62	33.89	33.12	32.55
Volume of Residue (mls)	876.53	861.27	828.27	816.74
Residue Yield (%)				
Mass Basis	98.59	97.04	95.07	93.37
Volume Basis	98.10	96.13	93.75	91.75
Evaporation Loss (%)				
Mass Basis	1.41	2.96	4.93	6.63
Volume Basis	1.90	3.87	6.25	8.25

TABLE V (Continued)

Run	D	E	F
Mass of Flask + Crude Oil (gms)	1129.00	1131.72	1139.72
Mass of Flask (gms)	375.67	375.62	375.62
Mass of Crude Oil (gms)	753.33	756.10	764.10
Density of Crude Oil at 60°F (gms/ml)	0.84673	0.84673	0.84673
Volume of Crude Oil (mls)	889.69	892.96	902.41
Start Evaporation	12:31	10:05	8:33
Stop Evaporation	3:41	2:25	2:13
Evaporation Time (mins)	190	260	340
Mass of Flask + Residue (gms)	1069.65	1064.70	1072.14
Mass of Flask (gms)	375.67	375.62	375.62
Mass of Residue (gms)	693.98	689.08	696.52

GRAVITY DETERMINATIONS ON EVAPORATION RESIDUES

Bottle	4	5	2	3	2	3
Mass of Bottle + Sample at 60°F (gms)	60.0844	58.8889	35.6623	35.5517	35.7109	35.6021
Mass of Bottle	16.7730	16.3840	13.8728	13.9988	13.8728	13.9988
Mass of Sample at 60°F (gms)	43.3114	42.5049	21.7895	21.5529	21.8381	21.6033
M.E.V.W. at 60°F (gms)	50.0942	49.1608	25.1549	24.8829	25.1549	24.8829
SG 60°F/60°F	0.86460	0.86461	0.86621	0.86617	0.86814	0.86820
Density of Sample at 60°F (gms/ml)	0.86377	0.86378	0.86538	0.86534	0.86731	0.86737

TABLE V (Continued)

Run	D	E	F
Average Density at $60^{\circ}F$ (gms/ml)	0.86377	0.86536	0.86734
Average SG $60^{\circ}F/60^{\circ}F$	0.86460	0.86619	0.86816
Average API Gravity (°)	32.16	31.86	31.49
Volume of Residue (mls)	803.43	796.29	803.05
Residue Yield (%)			
Mass Basis	92.12	91.14	91.16
Volume Basis	90.30	89.17	88.99
Evaporation Loss (%)			
Mass Basis	7.88	8.86	8.84
Volume Basis	9.70	10.83	11.01

TABLE VI

ENGLER TYPE DISTILLATION DATA ON TWLCC2 CRUDE OIL AND ITS RESIDUES

Charge	TWLCC2 Crude Oil	Residue Ha	G	B	C	D	E	F	A
Mass of Flask + Charge (gms)	486.69	481.49	493.21	467.43	488.01	473.58	473.01	487.79	476.56
Mass of Flask (gms)	212.54	212.44	212.54	192.96	212.56	197.49	197.55	212.56	197.35
Mass of Charge (gms)	274.15	269.05	280.67	274.47	275.45	279.09	275.46	275.23	279.21
Density of Charge at 60°F (gms/ml)	0.84673	0.85097	0.85475	0.85872	0.86169	0.86377	0.86536	0.86734	0.87292
Volume of Charge at 60°F (ml)	323.77	316.17	328.37	319.63	319.66	323.11	318.32	317.33	319.86
Barometric Pressure (mm Hg)	707.1	701.3	699.1	706.0	705.6	698.5	700.0	700.0	704.0
Initial Boiling Point (°F)	80	100	130	158	160	184	194	218	235
Temperature at end of Cut 1 (°F)	184	191	210	212	223	240	245	257	290
2	208	220	230	238	250	257	265	276	313
3	234	239	250	245	267	271	283	295	329
4	270	281	286	291	310	320	315	327	350
5	312	324	330	337	357	361	360	358	370
6	361	377	388	386	397	399	392	397	395
7	425	425	425	425	425	425	425	425	425
8									
Mass of Flask + Bottoms (gms)	395.41	393.72	391.01	387.09	408.36	395.90	399.55	418.31	415.81
Mass of Flask (gms)	212.54	212.44	212.54	192.96	212.56	197.49	197.55	212.56	197.35
Mass ob Bottoms (gms)	182.87	181.28	178.47	194.13	195.80	198.41	202.00	205.75	218.46

TABLE VI (Continued)

GRAVITY DETERMINATIONS ON DISTILLATION BOTTOMS

Charge	TWLCC2 Crude Oil	Residue Ha	G	B	C	D	E	F	A
Bottle	4	2	2	4	4	2	2	2	5
Mass of Bottle + Sample (gms)	61.9112	36.5435	36.5323	61.8855	61.9424	36.5544	36.5329	36.5265	60.6199
Mass of Bottle (gms)	16.7730	13.8728	13.8728	16.7730	16.7730	13.8728	13.8728	13.8728	16.3840
Mass of Sample at 60°F (gms)	45.1382	22.6707	22.6595	45.1125	45.1694	22.6816	22.6601	22.6537	44.2359
M.E.V.W. at 60°F (gms)	50.0942	25.1549	25.1549	50.0942	50.0942	25.1549	25.1549	25.1549	49.1608
SG 60°F/60°F	0.90107	0.90124	0.90080	0.90055	0.90169	0.90168	0.90082	0.90057	0.89982
API Gravity of Bottoms (°)	25.54	25.50	25.58	25.63	25.43	25.43	25.58	25.62	25.75
Density of Bottoms at 60°F (gms/ml)	0.90021	0.90038	0.89994	0.89969	0.90082	0.90081	0.89996	0.89971	0.89896
Volume of Bottoms (ml)	203.14	201.34	198.31	215.77	217.36	220.26	224.45	228.68	243.01
Mass Percent Bottoms (%)	66.70	67.38	63.59	70.73	71.08	71.09	73.33	74.76	78.24
Volume Percent Bottoms (%)	62.74	63.68	60.39	67.51	68.00	68.17	70.51	72.06	75.97

TABLE VII

HEMPEL TYPE DISTILLATION DATA ON TWLCC2 CRUDE OIL AND ITS RESIDUES

Charge	TWLCC2 Crude Oil	Residue Ha	G	B	C	D	E	F	A
Mass of Flask + Charge (gms)	626.51	627.45	629.12	641.49	631.00	645.15	632.63	627.50	604.65
Mass of Flask (gms)	356.33	356.22	356.67	366.85	356.35	371.37	371.40	356.50	356.19
Mass of Charge (gms)	270.18	271.23	272.45	274.64	274.65	273.78	261.23	271.00	248.46
Density of Charge at 60°F (gms/ml)	0.84673	0.85097	0.85475	0.85872	0.86169	0.86377	0.86536	0.86734	0.87292
Volume of Charge at 60°F (mls)	319.09	318.73	318.75	319.82	318.73	316.96	301.87	312.45	284.63
Barometric Pressure (mm Hg)	707.1	701.3	699.1	706.0	705.6	698.5	700.0	700.0	706.6
Initial Boiling Point (°F)	68	79	90	90	150	140	105	186	98
Vapor Temp. (°F) at end of Fraction 1	164	173	177	193	203	210	220	235	258
2	190	198	200	217	225	232	246	252	285
3	210	217	220	238	246	253	270	275	311
4	246	236	268	285	295	300	310	308	334
5	306	285	313	330	345	350	348	345	389
6	366	334	369	385	397	390	391	385	425
7	425	388	425	425	425	425	425	425	
8		425							
Mass of Flask + Bottoms (gms)	534.25	537.80	542.57	559.17	551.67	566.87	561.75	556.10	545.64
Mass of Flask (gms)	356.33	356.22	356.67	366.85	356.35	371.37	371.40	356.50	356.19
Mass of Bottoms (gms)	177.92	181.58	185.90	192.32	195.32	195.50	190.35	199.60	189.45

TABLE VII (Continued)

GRAVITY DETERMINATIONS ON DISTILLATION BOTTOMS

Charge	TWLCC2 Crude Oil	Residue Ha	G	B	C	D	E	F	A
Bottle	5	3	3	5	5	3	3	3	4
Mass of Bottle + Sample (gms)	60.7714	36.4684	36.4432	60.7493	60.7629	36.4859	36.4540	36.4545	62.0517
Mass of Bottle (gms)	16.3840	13.9988	13.9988	16.3840	16.3840	13.9988	13.9988	13.9988	16.7730
Mass of Sample at $60^{o}F$ (gms)	44.3874	29.4696	22.4444	44.3653	44.3789	22.4871	22.4552	22.4557	45.2787
M.E.V.W. at $60^{o}F$ (gms)	49.1608	24.8829	24.8829	49.1608	49.1608	24.8829	24.8829	24.8829	50.0942
SG $60^{o}F/60^{o}F$	0.90290	0.90301	0.90200	0.90245	0.90273	0.90372	0.90244	0.90246	0.90387
API Gravity of Bottoms (^{o})	25.22	25.20	25.37	25.30	25.25	25.08	25.30	25.29	25.05
Density of Bottoms at $60^{o}F$ (gms/ml)	0.90203	0.90214	0.90113	0.90158	0.90186	0.90285	0.90157	0.90159	0.90300
Volume of Bottoms (mls)	197.24	201.28	206.30	213.31	216.57	216.54	211.13	221.39	209.80
Mass Percent Bottoms (%)	65.85	66.95	68.23	70.03	71.12	71.41	72.87	73.65	76.25
Volume Percent Bottoms (%)	61.81	63.15	64.72	66.70	67.95	68.32	69.94	70.86	73.71

TABLE VIII

EXAMINATION OF DISTILLATE FRACTIONS

ENGLER TYPE DISTILLATION ON TWLCC2 CRUDE OIL

Fraction	1	2	3	4	5	6	7
Receiver	8W	9W	10W	11W	12W	9B	10B
Mass of Receiver (gms)	25.4410	24.5707	23.7775	24.7459	24.7812	29.1558	28.2669
Stopper	1	2	3	4	5	6	7
Mass of Stopper (gms)	1.2130	1.5819	1.1642	1.6466	1.3060	1.4557	1.2141
Mass of Hanger (gms)	3.1420	3.1420	3.1420	3.1420	3.1420	3.1420	3.1420
Mass of RSH (gms)	29.7960	29.2946	28.0837	29.5345	29.2292	33.7535	32.5330
Mass of Fraction + RSH (gms)	36.9543	36.1033	35.5910	44.3417	43.9656	49.0268	52.3457
Mass of RSH (gms)	29.7960	29.2946	28.0837	29.5345	29.2292	33.7535	32.5330
Mass of Fraction (gms)	7.1583	6.8087	7.5073	14.8072	14.7364	15.2733	19.8127
Pycnometer	A	C	H	J	D	K	B
Mass of Pyc. + Sample (gms)	15.8864	16.5590	17.0353	15.2311	17.2414	15.7356	14.2898
Mass of Pyc. (gms)	13.2900	14.0033	14.6170	12.9503	15.0672	13.5339	12.2235
Mass of Sample at 60°F (gms)	2.5964	2.5557	2.4183	2.2808	2.1742	2.2017	2.0663
M.E.V.W. at 60°F (gms)	3.7134	3.5578	3.2904	3.0306	2.8263	2.7886	2.5327
SG 60°F/60°F	0.69920	0.71834	0.73496	0.75259	0.76927	0.78954	0.81585
API Gravity (°)	70.87	65.48	61.03	56.52	52.44	47.72	41.94
Density at 60°F (gms/ml)	0.69853	0.71765	0.73425	0.75187	0.76853	0.78878	0.81507
Volume of Fraction (mls)	10.25	9.49	10.22	19.69	19.17	19.36	24.31

* RSH = Receiver + Stopper + Hanger

TABLE VIII (Continued)

ENGLER TYPE DISTILLATION ON RESIDUE Ha

Fraction	1	2	3	4	5	6	7
Receiver	1W	2W	3W	4W	5W	6W	7W
Mass of Receiver (gms)	25.7191	26.3215	25.7077	26.9040	24.8536	25.2972	25.3757
Stopper	15	16	17	18	19	20	21
Mass of Stopper (gms)	1.4877	1.1225	1.2042	1.3982	1.4420	1.1086	1.2982
Mass of Hanger (gms)	3.1420	3.1420	3.1420	3.1420	3.1420	3.1420	3.1420
Mass of RSH (gms)	30.3488	30.5860	30.0539	31.4442	29.4376	29.5478	29.8159
Mass of Fraction + RSH (gms)	37.2064	37.6997	37.1667	46.6078	44.8937	45.4869	46.8217
Mass of RSH (gms)	30.3488	30.5860	30.0539	31.4442	29.4376	29.5478	29.8159
Mass of Fraction (gms)	6.8576	7.1137	7.1128	15.1636	15.4561	15.9391	17.0058
Pycnometer	A	H	J	D	K	B	C
Mass of Pyc. + Sample (gms)	15.9220	17.0587	15.2321	17.2836	15.7568	14.2523	16.9467
Mass of Pyc. (gms)	13.2900	14.6170	12.9503	15.0672	13.5339	12.2235	14.0033
Mass of Sample at 60°F (gms)	2.6320	2.4417	2.2818	2.2164	2.2229	2.0288	2.9434
M.E.V.W. at 60°F (gms)	3.7134	3.2904	3.0306	2.8263	2.7886	2.5327	3.5578
SG 60°F/60°F	0.70878	0.74207	0.75292	0.78421	0.79714	0.80104	0.82731
API Gravity (°)	68.14	59.18	56.43	48.94	46.01	45.15	39.54
Density at 60°F (gms/ml)	0.70810	0.74136	0.75220	0.78346	0.79637	0.80027	0.82652
Volume of Fraction (mls)	9.68	9.60	9.46	19.35	19.41	19.92	20.58

* RSH = Receiver + Stopper + Hanger

TABLE VIII (Continued)

ENGLER TYPE DISTILLATION ON RESIDUE G

Fraction	1	2	3	4	5	6	7
Receiver	8W	9W	10W	11W	12W	9B	10B
Mass of Receiver (gms)	25.4410	24.5707	23.7775	24.7459	24.7812	29.1558	28.2669
Stopper	1	2	3	4	5	6	7
Mass of Stopper (gms)	1.2130	1.5819	1.1642	1.6466	1.3060	1.4557	1.1241
Mass of Hanger (gms)	3.1420	3.1420	3.1420	3.1420	3.1420	3.1420	3.1420
Mass of RSH (gms)	29.7960	29.2946	28.0837	29.5345	29.2292	33.7535	32.5330
Mass of Fraction + RSH (gms)	37.6388	36.6250	36.0778	44.5139	44.7520	49.6258	46.2460
Mass of RSH (gms)	29.7960	29.2946	28.0837	29.5345	29.2292	33.7535	32.5330
Mass of Fraction (gms)	7.8428	7.3304	7.9941	14.9794	15.5228	15.8723	13.1730
Pycnometer	A	H	J	D	K	B	C
Mass of Pyc. + Sample (gms)	15.9805	17.0382	15.2197	17.2129	15.7074	14.2458	16.9088
Mass of Pyc. (gms)	13.2900	14.6170	12.9503	15.0672	13.5339	12.2235	14.0033
Mass of Sample at 60°F (gms)	2.6905	2.4212	2.2694	2.1457	2.1735	2.0223	2.9055
M.E.V.W. at 60°F (gms)	3.7134	3.2904	3.0306	2.8263	2.7886	2.5327	3.5578
SG 60°F/60°F	0.72454	0.73584	0.74883	0.75919	0.77942	0.79848	0.81666
API Gravity (°)	63.80	60.80	57.46	54.88	50.05	45.71	41.77
Density at 60°F (gms/ml)	0.72384	0.73514	0.74811	0.75846	0.77867	0.79771	0.81588
Volume of Fraction (mls)	10.83	9.97	10.69	10.01	19.94	19.90	16.15

* RSH = Receiver + Stopper + Hanger

TABLE VIII (Continued)

ENGLER TYPE DISTILLATION ON RESIDUE B

Fraction	1	2	3	4	5	6	7
Receiver	2B	3B	4B	5B	6B	7B	8B
Mass of Receiver (gms)	27.7437	27.3972	27.5957	29.1287	29.0649	29.0833	27.7933
Stopper	8	9	10	11	12	13	14
Mass of **Stopper** (gms)	1.2438	1.4066	1.4768	1.6079	1.1435	1.4346	1.2368
Mass of Hanger (gms)	3.1420	3.1420	3.1420	3.1420	3.1420	3.1420	3.1420
Mass of RSH (gms)	32.1295	31.9458	32.2145	33.8786	33.3504	33.6599	32.1721
Mass of Fraction + RSH (gms)	38.9965	38.8173	39.1604	48.6602	48.5532	49.1053	44.6558
Mass of RSH (gms)	32.1295	31.9458	32.2145	33.8786	33.3504	33.6599	32.1721
Mass of Fraction (gms)	6.8670	6.8715	6.9459	14.7816	15.2028	15.4454	12.4837
Pycnometer	A	H	J	D	K	B	C
Mass of Pyc. + Sample (gms)	16.1051	17.0759	15.2534	17.2254	15.7152	14.2538	16.9102
Mass of Pyc. (gms)	13.2900	14.6170	12.9503	15.0672	13.5339	12.2235	14.0033
Mass of Sample at $60^{\circ}F$ (gms)	2.8151	2.4589	2.3031	2.1582	2.1813	2.0303	2.9069
M.E.V.W. at $60^{\circ}F$ (gms)	3.7134	3.2904	3.0306	2.8263	2.7886	2.5327	3.5578
SG $60^{\circ}F/60^{\circ}F$	0.75809	0.74730	0.75995	0.76361	0.78222	0.80163	0.81705
API Gravity ($^{\circ}$)	55.15	57.85	54.70	53.80	49.40	45.02	41.68
Density at $60^{\circ}F$ (gms/ml)	0.75736	0.74658	0.75922	0.76288	0.78147	0.80086	0.81627
Volume of Fraction (mls)	9.07	9.20	9.15	19.38	19.45	19.29	15.29

* RSH = Receiver + Stopper + Hanger

TABLE VIII (Continued)

ENGLER TYPE DISTILLATION ON RESIDUE C

Fraction	1	2	3	4	5	6	7
Receiver	1W	2W	3W	4W	5W	6W	7W
Mass of Receiver (gms)	25.7191	26.3215	25.7077	26.9040	24.8536	25.2972	25.3757
Stopper	15	16	17	18	19	20	21
Mass of Stopper (gms)	1.4877	1.1225	1.2042	1.3982	1.4420	1.1086	1.2982
Mass of Hanger (gms)	3.1420	3.1420	3.1420	3.1420	3.1420	3.1420	3.1420
Mass of RSH (gms)	30.3488	30.5860	30.0539	31.4442	29.4376	29.5478	29.8159
Mass of Fraction + RSH (gms)	37.5774	38.0550	37.4378	47.1601	44.8533	45.1581	39.1544
Mass of RSH (gms)	30.3488	30.5860	30.0539	31.4442	29.4376	29.5478	29.8159
Mass of Fraction (gms)	7.2286	7.4690	7.3839	15.7159	15.4157	15.6103	9.3385
Pycnometer	A	H	J	D	K	B	C
Mass of Pyc. + Sample (gms)	16.0458	17.0901	15.2441	17.2422	15.7304	14.2683	16.9218
Mass of Pyc. (gms)	13.2900	14.6170	12.9503	15.0672	13.5339	12.2235	14.0033
Mass of Sample at 60^{o}F (gms)	2.7558	2.4731	2.2938	2.1750	2.1965	2.0448	2.9185
M.E.V.W. at 60^{o}F (gms)	3.7134	3.2904	3.0306	2.8263	2.7886	2.5327	3.5578
SG 60^{o}F/60^{o}F	0.74212	0.75161	0.75688	0.76956	0.78767	0.80736	0.82031
API Gravity (^{o})	59.17	56.76	55.45	52.37	48.14	43.76	41.00
Density at 60^{o}F (gms/ml)	0.74142	0.75089	0.75615	0.76882	0.78691	0.80659	0.81952
Volume of Fraction (mls)	9.75	9.95	9.77	20.44	19.59	19.35	11.40

* RSH = Receiver + Stopper + Hanger

TABLE VIII (Continued)

ENGLER TYPE DISTILLATION ON RESIDUE D

Fraction	1	2	3	4	5	6	7
Receiver	8W	9W	10W	11W	12W	9B	10B
Mass of Receiver (gms)	25.4410	24.5707	23.7775	24.7459	24.7812	29.1558	28.2669
Stopper	1	2	3	4	5	6	7
Mass of Stopper (gms)	1.2130	1.5819	1.1642	1.6466	1.3060	1.4557	1.1241
Mass of Hanger (gms)	3.1420	3.1420	3.1420	3.1420	3.1420	3.1420	3.1420
Mass of RSH (gms)	29.7960	29.2946	28.0837	29.5345	29.2292	33.7535	32.5330
Mass of Fraction + RSH (gms)	37.5859	36.9599	35.7865	45.0551	44.8473	46.0299	42.5936
Mass of RSH (gms)	29.7960	29.2946	28.0837	29.5345	29.2292	33.7535	32.5330
Mass of Fraction (gms)	7.7899	7.6653	7.7028	15.5206	15.6181	12.2764	10.0606
Pycnometer	A	H	J	D	K	B	C
Mass of Pyc. + Sample (gms)	16.0623	17.1072	15.2628	17.2569	15.7400	14.2671	16.9145
Mass of Pyc. (gms)	13.2900	14.6170	12.9503	15.0672	13.5339	12.2235	14.0033
Mass of Sample at 60^oF (gms)	2.7723	2.4902	2.3125	2.1897	2.2061	2.0436	2.9112
M.E.V.W. at 60^oF (gms)	3.7134	3.2904	3.0306	2.8263	2.7886	2.5327	3.5578
SG $60^oF/60^oF$	0.74657	0.75681	0.76305	0.77476	0.79111	0.80689	0.81826
API Gravity (^{o})	58.03	55.47	53.94	51.14	47.36	43.86	41.43
Density at 60^oF (gms/ml)	0.74585	0.75608	0.76232	0.77402	0.79035	0.80612	0.81747
Volume of Fraction (mls)	10.44	10.14	10.10	20.05	19.76	15.23	12.31

* RSH = Receiver + Stopper + Hanger

TABLE VIII (Continued)

ENGLER TYPE DISTILLATION ON RESIDUE E

Fraction	1	2	3	4	5	6	7
Receiver	2B	3B	4B	5B	6B	7B	8B
Mass of Receiver (gms)	27.7437	27.3972	27.5957	29.1287	29.0649	29.0833	27.7933
Stopper	8	9	10	11	12	13	14
Mass of Stopper (gms)	1.2438	1.4066	1.4768	1.6079	1.1435	1.4346	1.2368
Mass of Hanger (gms)	3.1420	3.1420	3.1420	3.1420	3.1420	3.1420	3.1420
Mass of RSH (gms)	32.1295	31.9458	32.2145	33.8786	33.3504	33.6599	32.1721
Mass of Fraction + RSH (gms)	39.3994	39.4570	39.6393	45.5753	48.9112	45.6562	43.4564
Mass of RSH (gms)	32.1295	31.9458	32.2145	33.8786	33.3504	33.6599	32.1721
Mass of Fraction (gms)	7.2699	7.5112	7.4248	11.6967	15.5608	11.9963	11.2843
Pycnometer	A	H	J	D	K	B	C
Mass of Pyc. + Sample (gms)	16.0958	17.1200	15.2767	17.2686	15.7368	14.2656	16.9188
Mass of Pyc. (gms)	13.2900	14.6170	12.9503	15.0672	13.5339	12.2235	14.0033
Mass of Sample at 60°F (gms)	2.8058	2.5030	2.3264	2.2014	2.2029	2.0421	2.9155
M.E.V.W. at 60°F (gms)	3.7134	3.2904	3.0306	2.8263	2.7886	2.5327	2.5578
SG 60°F/60°F	0.75559	0.76070	0.76764	0.77890	0.78997	0.80629	0.81947
API Gravity ($^\circ$)	55.77	54.51	52.83	50.17	47.62	44.00	41.17
Density at 60°F (gms/ml)	0.75486	0.75997	0.76690	0.77815	0.78921	0.80552	0.81868
Volume of Fraction (mls)	9.63	9.88	9.68	15.03	19.72	14.89	13.78

* RSH = Receiver + Stopper + Hanger

TABLE VIII (Continued)

ENGLER TYPE DISTILLATION ON RESIDUE F

Fraction	1	2	3	4	5	6	7
Receiver	1W	2W	3W	4W	5W	6W	7W
Mass of Receiver (gms)	25.7191	26.3215	25.7077	26.9040	24.8536	25.2972	25.3757
Stopper	15	16	17	18	19	20	21
Mass of Stopper (gms)	1.4877	1.1225	1.2042	1.3982	1.4420	1.1086	1.2982
Mass of Hanger (gms)	3.1420	3.1420	3.1420	3.1420	3.1420	3.1420	3.1420
Mass of RSH (gms)	30.3488	30.5860	30.0539	31.4442	29.4376	29.5478	29.8159
Mass of Fraction + RSH (gms)	37.5341	37.5141	37.4944	43.4450	41.2245	41.2699	41.6498
Mass of RSH (gms)	30.3488	30.5860	30.0539	31.4442	29.4376	29.5478	29.8159
Mass of Fraction (gms)	7.1853	6.9281	7.4405	12.0008	11.7869	11.7221	11.8339
Pycnometer	A	H	J	D	K	B	C
Mass of Pyc. + Sample (gms)	16.0994	17.1312	15.2888	17.2679	15.7357	14.2604	16.9140
Mass of Pyc. (gms)	13.2900	14.6170	12.9503	15.0672	13.5339	12.2235	14.0033
Mass of Sample at 60°F (gms)	2.8094	2.5142	2.3385	2.2007	2.2018	2.0369	2.9107
M.E.V.W. at 60°F (gms)	3.7134	3.2904	3.0306	2.8263	2.7886	2.5327	3.5578
SG 60°F/60°F	0.75656	0.76410	0.77163	0.77865	0.78957	0.80424	0.81812
API Gravity (°)	55.53	53.69	51.88	50.22	47.71	44.44	41.46
Density at 60°F (gms/ml)	0.75583	0.76337	0.77089	0.77790	0.78881	0.80347	0.81733
Volume of Fraction (mls)	9.51	9.08	9.65	15.43	14.94	14.59	14.48

* RSH = Receiver + Stopper + Hanger

TABLE VIII (Continued)

ENGLER TYPE DISTILLATION ON RESIDUE A

Fraction	1	2	3	4	5	6	7
Receiver	2B	3B	4B	5B	6B	7B	8B
Mass of Receiver (gms)	27.7437	27.3972	27.5957	29.1287	29.0649	29.0833	27.7933
Stopper	1	2	3	4	5	6	7
Mass of Stopper (gms)	1.2130	1.5819	1.1642	1.6466	1.3060	1.4557	1.1241
Mass of Hanger (gms)	3.1420	3.1420	3.1420	3.1420	3.1420	3.1420	3.1420
Mass of RSH (gms)	32.0987	32.1211	31.9019	33.9173	33.5129	33.6810	32.0594
Mass of Fraction + RSH (gms)	39.6184	39.7790	39.6739	41.7125	40.9019	41.7390	44.4294
Mass of RSH (gms)	32.0987	32.1211	31.9019	33.9173	33.5129	33.6810	32.0594
Mass of Fraction (gms)	7.5197	7.6579	7.7720	7.7952	7.3890	8.0580	12.3700
Pycnometer	A	C	H	J	D	K	B
Mass of Pyc. + Sample (gms)	16.1382	16.7587	17.1959	15.3458	17.3262	15.7906	14.2952
Mass of Pyc. (gms)	13.2900	14.0033	14.6170	12.9503	15.0672	13.5339	12.2235
Mass of Sample at $60^{\circ}F$ (gms)	2.8482	2.7554	2.5789	2.3955	2.2590	2.2567	2.0717
M.E.V.W. at $60^{\circ}F$ (gms)	3.7134	3.5578	3.2904	3.0306	2.8263	2.7886	2.5327
SG $60^{\circ}F/60^{\circ}F$	0.76701	0.77447	0.78376	0.79044	0.79928	0.80926	0.81798
API Gravity (°)	52.98	51.21	49.04	47.51	45.53	43.35	41.49
Density at $60^{\circ}F$ (gms/ml)	0.76627	0.77373	0.78301	0.78968	0.79851	0.80858	0.81719
Volume of Fraction (mls)	9.81	9.90	9.93	9.87	9.25	9.97	15.14

* RSH = Receiver + Stopper + Hanger

TABLE VIII (Continued)

HEMPEL TYPE DISTILLATION ON TWLCC2 CRUDE OIL

Fraction	1	2	3	4	5	6	7
Receiver	1W	2W	3W	4W	5W	6W	7W
Mass of Receiver (gms)	25.7191	26.3215	25.7077	26.9040	24.8536	25.2972	25.3757
Stopper	15	17	16	18	19	20	21
Mass of Stopper (gms)	1.4877	1.2042	1.1225	1.3982	1.4420	1.1086	1.2982
Mass of Hanger (gms)	3.1420	3.1420	3.1420	3.1420	3.1420	3.1420	3.1420
Mass of RSH (gms)	30.3488	30.6677	29.9722	31.4442	29.4376	29.5478	29.8159
Mass of Fraction + RSH (gms)	37.0673	37.8108	37.3686	46.6328	44.5363	45.3302	48.9656
Mass of RSH (gms)	30.3488	30.6677	29.9722	31.4442	29.4376	29.5478	29.8159
Mass of Fraction (gms)	6.7185	7.1431	7.3964	15.1886	15.0987	15.7824	19.1497
Pycnometer	A	C	H	J	D	K	B
Mass of Pyc. + Sample (gms)	15.8221	16.6020	17.0405	15.2375	17.2504	15.7500	14.2974
Mass of Pyc. (gms)	13.2900	14.0033	14.6170	12.9503	15.0672	13.5339	12.2235
Mass of Sample at 60°F (gms)	2.5321	2.5987	2.4235	2.2872	2.1832	2.2161	2.0739
M.E.V.W. at 60°F (gms)	3.7134	3.5578	3.2904	3.0306	2.8263	2.7886	2.5327
SG 60°F/60°F	0.68188	0.73042	0.73654	0.75470	0.77246	0.79470	0.81885
API Gravity (°)	76.01	62.22	60.61	55.99	51.68	56.55	41.30
Density at 60°F (gms/ml)	0.68123	0.72972	0.73583	0.75398	0.77172	0.79394	0.81806
Volume of Fraction (mls)	9.86	9.79	10.05	20.14	19.56	19.88	23.41

* RSH = Receiver + Stopper + Hanger

TABLE VIII (Continued)

HEMPEL TYPE DISTILLATION ON RESIDUE Ha

Fraction	1	2	3	4	5	6	7	8
Receiver	2B	3B	4B	5B	6B	7B	8B	11B
Mass of Receiver (gms)	27.7437	27.3972	27.5957	29.1287	29.0649	29.0833	27.7933	28.8103
Stopper	8	9	10	11	12	13	14	23
Mass of Stopper (gms)	1.2438	1.4066	1.4768	1.6079	1.1435	1.4346	1.2368	1.4274
Mass of Hanger (gms)	3.1420	3.1420	3.1420	3.1420	3.1420	3.1420	3.1420	3.1420
Mass of RSH (gms)	32.1295	31.9458	32.2145	33.8786	33.3504	33.6599	32.1721	33.3797
Mass of Fraction + RSH (gms)	38.8675	39.0218	39.3847	41.0185	48.5502	49.1751	47.9669	45.6437
Mass of RSH (gms)	32.1295	31.9458	32.2145	33.8786	33.3504	33.6599	32.1721	33.3797
Mass of Fraction (gms)	6.7380	7.0760	7.1702	7.1399	15.1998	15.5152	15.7948	12.2640
Pycnometer	A	H	J	D	K	B	C	F
Mass of Pyc. + Sample (gms)	15.8608	17.0455	15.2302	17.2625	15.7067	14.2266	16.9222	16.2154
Mass of Pyc. (gms)	13.2900	14.6170	12.9503	15.0672	13.5339	12.2235	14.0033	14.3179
Mass of Sample at 60°F (gms)	2.5708	2.4285	2.2799	2.1953	2.1728	2.0031	2.9189	1.8975
M.E.V.W. at 60°F (gms)	3.7134	3.2904	3.0306	2.8263	2.7886	2.5327	3.5578	2.3049
SG 60°F/60°F	0.69230	0.73806	0.75229	0.77674	0.77917	0.79090	0.82042	0.82325
API Gravity (°)	72.89	60.22	56.59	50.67	50.10	47.41	40.97	40.38
Density at 60°F (gms/ml)	0.69164	0.73735	0.75157	0.77599	0.77842	0.79014	0.81963	0.82246
Volume of Fraction (mls)	9.74	9.60	9.54	9.20	19.53	19.64	19.27	14.91

* RSH = Receiver + Stopper + Hanger

TABLE VIII (Continued)

HEMPEL TYPE DISTILLATION ON RESIDUE G

Fraction	1	2	3	4	5	6	7
Receiver	1W	2W	3W	4W	5W	6W	7W
Mass of Receiver (gms)	25.7191	26.3215	25.7077	26.9040	24.8536	25.2972	25.3757
Stopper	15	16	17	18	19	20	21
Mass of Stopper (gms)	1.4877	1.1225	1.2042	1.3982	1.4420	1.1086	1.2982
Mass of Hanger (gms)	3.1420	3.1420	3.1420	3.1420	3.1420	3.1420	3.1420
Mass of RSH (gms)	30.3488	30.5860	30.0539	31.4442	29.4376	29.5478	29.8159
Mass of Fraction + RSH (gms)	37.0436	37.6905	37.3599	46.5117	44.8672	45.5782	47.3130
Mass of RSH (gms)	30.3488	30.5860	30.0539	31.4442	29.4376	29.5478	29.8159
Mass of Fraction (gms)	6.6948	7.1045	7.3060	15.0675	15.4296	16.0304	17.4971
Pycnometer	H	A	J	D	K	B	C
Mass of Pyc. + Sample (gms)	16.9223	16.0283	15.2390	17.2499	15.2926	14.2695	16.9156
Mass of Pyc. (gms)	14.6170	13.2900	12.9503	15.0672	13.5339	12.2235	14.0033
Mass of Sample at $60^\circ F$ (gms)	2.3053	2.7383	2.2887	2.1827	1.7587	2.0460	2.9123
M.E.V.W. at $60^\circ F$ (gms)	3.2904	3.7134	3.0306	2.8263	2.7886	2.5327	3.5578
SG $60^\circ F/60^\circ F$	0.70061	0.73741	0.75520	0.77228	0.63067	0.80783	0.81857
API Gravity (°)	70.47	60.39	55.87	51.72	92.86	45.66	41.36
Density at $60^\circ F$ (gms/ml)	0.69994	0.73670	0.75448	0.77154	0.63065	0.80705	0.81778
Volume of Fraction (mls)	9.56	9.64	9.68	19.53	24.47	19.86	21.40

* RSH = Receiver + Stopper + Hanger

TABLE VIII (Continued)

HEMPEL TYPE DISTILLATION ON RESIDUE B

Fraction	1	2	3	4	5	6	7
Receiver	8W	9W	10W	11W	12W	9B	10B
Mass of Receiver (gms)	25.4410	24.5707	23.7775	24.7459	24.7812	29.1558	28.2669
Stopper	1	2	3	4	5	6	7
Mass of Stopper (gms)	1.2130	1.5819	1.1642	1.6466	1.3060	1.4557	1.1241
Mass of Hanger (gms)	3.1420	3.1420	3.1420	3.1420	3.1420	3.1420	3.1420
Mass of RSH (gms)	29.7960	29.2946	28.0837	29.5345	29.2292	33.7535	32.5330
Mass of Fraction + RSH (gms)	36.6760	36.3998	35.3704	44.6732	44.8585	49.6094	44.9317
Mass of RSH (gms)	29.7960	29.2946	28.0837	29.5345	29.2292	33.7535	32.5330
Mass of Fraction (gms)	6.8800	7.1052	7.2867	15.1387	15.6293	15.8559	12.3987
Pycnometer	A	H	J	D	K	B	C
Mass of Pyc. + Sample (gms)	16.0035	17.0528	15.2290	17.2191	15.7133	14.2583	16.9172
Mass of Pyc. (gms)	13.2900	14.6170	12.9503	15.0672	13.5339	12.2235	14.0033
Mass of Sample at 60°F (gms)	2.7135	2.4358	2.2787	2.1519	2.1794	2.0348	2.9139
M.E.V.W. at 60°F (gms)	3.7134	3.2904	3.0306	2.8263	2.7886	2.5327	3.5578
SG 60°F/60°F	0.73073	0.74027	0.75190	0.76138	0.78154	0.80341	0.81902
API Gravity (°)	62.14	59.65	56.69	54.35	49.55	44.62	41.27
Density at 60°F (gms/ml)	0.73003	0.73956	0.75118	0.76065	0.78079	0.80264	0.81824
Volume of Fraction (mls)	9.42	9.61	9.70	19.90	20.02	19.75	15.15

* RSH = Receiver + Stopper + Hanger

TABLE VIII (Continued)

HEMPEL TYPE DISTILLATION ON RESIDUE C

Fraction	1	2	3	4	5	6	7
Receiver	2B	3B	4B	5B	6B	7B	8B
Mass of Receiver (gms)	27.7437	27.3972	27.5957	29.1287	29.0649	29.0833	27.7933
Stopper	8	9	10	11	12	13	14
Mass of Stopper (gms)	1.2438	1.4066	1.4768	1.6079	1.1435	1.4346	1.2368
Mass of Hanger (gms)	3.1420	3.1420	3.1420	3.1420	3.1420	3.1420	3.1420
Mass of RSH (gms)	32.1295	31.9458	32.2145	33.8786	33.3504	33.6599	32.1721
Mass of Fraction + RSH (gms)	39.1745	39.1036	39.5835	49.1181	48.9442	49.3883	42.4866
Mass of RSH (gms)	32.1295	31.9458	32.2145	33.8786	33.3504	33.6599	32.1721
Mass of Fraction (gms)	7.0450	7.1578	7.3690	15.2395	15.5938	15.7284	10.3145
Pycnometer	A	H	J	D	K	B	C
Mass of Pyc. + Sample (gms)	16.0022	17.0658	15.2272	17.2314	15.7263	14.2678	16.9229
Mass of Pyc. (gms)	13.2900	14.6170	12.9503	15.0672	13.5339	12.2235	14.0033
Mass of Sample at $60^{\circ}F$ (gms)	2.7122	2.4488	2.2769	2.1642	2.1924	2.0443	2.9196
M.E.V.W. at $60^{\circ}F$ (gms)	3.7134	3.2904	3.0306	2.8263	2.7886	2.5327	3.5578
SG $60^{\circ}F/60^{\circ}F$	0.73038	0.74423	0.75130	0.76574	0.78620	0.80716	0.82062
API Gravity (°)	62.23	58.63	56.84	53.29	48.48	43.81	40.93
Density at $60^{\circ}F$ (gms/ml)	0.72968	0.74352	0.75058	0.76501	0.78545	0.80639	0.81983
Volume of Fraction (mls)	9.65	9.63	9.82	19.92	19.85	19.50	12.58

* RSH = Receiver + Stopper + Hanger

TABLE VIII (Continued)

HEMPEL TYPE DISTILLATION ON RESIDUE D

Fraction	1	2	3	4	5	6	7
Receiver	1W	2W	3W	4W	5W	6W	7W
Mass of Receiver (gms)	25.7191	26.3215	25.7077	26.9040	24.8536	25.2972	25.3757
Stopper	15	16	17	18	19	20	21
Mass of Stopper (gms)	1.4877	1.1225	1.2042	1.3982	1.4420	1.1086	1.2982
Mass of Hanger (gms)	3.1420	3.1420	3.1420	3.1420	3.1420	3.1420	3.1420
Mass of RSH (gms)	30.3488	30.5860	30.0539	31.4442	29.4376	29.5478	29.8159
Mass of Fraction + RSH (gms)	37.0521	38.6768	37.4222	46.7576	45.1715	41.2241	42.1237
Mass of RSH (gms)	30.3488	30.5860	30.0539	31.4442	29.4376	29.5478	29.8159
Mass of Fraction (gms)	6.7033	8.0908	7.3683	15.3134	15.7339	11.6763	12.3078
Pycnometer	A	H	J	D	K	B	C
Mass of Pyc. + Sample (gms)	16.0408	17.0840	15.2537	17.2710	15.8236	14.3324	16.9264
Mass of Pyc. (gms)	13.2900	14.6170	12.9503	15.0672	13.5339	12.2235	14.0033
Mass of Sample at 60°F (gms)	2.7508	2.4670	2.3034	2.2038	2.2897	2.1089	2.9231
M.E.V.W. at 60°F (gms)	3.7134	3.2904	3.0306	2.8263	2.7886	2.5327	3.5578
SG 60°F/60°F	0.74078	0.74976	0.76005	0.77975	0.82109	0.83267	0.82160
API Gravity ($^\circ$)	59.51	57.23	54.67	49.97	40.83	38.44	40.72
Density at 60°F (gms/ml)	0.74007	0.74904	0.75932	0.77900	0.82030	0.83187	0.82081
Volume of Fraction (mls)	9.06	10.80	9.70	19.66	19.18	14.04	14.99

* RSH = Receiver + Stopper + Hanger

TABLE VIII (Continued)

HEMPEL TYPE DISTILLATION ON RESIDUE E

Fraction	1	2	3	4	5	6	7
Receiver	8W	9W	10W	11W	12W	9B	10B
Mass of Receiver (gms)	25.4410	24.5707	23.7775	24.7459	24.7812	29.1558	28.2669
Stopper	1	2	3	4	5	6	7
Mass of Stopper (gms)	1.2130	1.5819	1.1642	1.6466	1.3060	1.4557	1.1241
Mass of Hanger (gms)	3.1420	3.1420	3.1420	3.1420	3.1420	3.1420	3.1420
Mass of RSH (gms)	29.7960	29.2946	28.0837	29.5345	29.2292	33.7535	32.5330
Mass of Fraction + RSH (gms)	37.0440	36.6866	35.7165	41.1696	41.0875	45.8356	44.7802
Mass of RSH (gms)	29.7960	29.2946	28.0837	29.5345	29.2292	33.7535	32.5330
Mass of Fraction (gms)	7.2480	7.3920	7.6328	11.6351	11.8583	12.0821	12.2472
Pycnometer	A	H	J	D	K	B	C
Mass of Pyc. + Sample (gms)	16.0412	17.0921	15.2568	17.2572	15.7405	14.2665	16.9149
Mass of Pyc. (gms)	13.2900	14.6170	12.9503	15.0672	13.5339	12.2235	14.0033
Mass of Sample at 60^oF (gms)	2.7512	2.4751	2.3065	2.1900	2.2066	2.0430	2.9116
M.E.V.W. at 60^oF (gms)	3.7134	3.2904	3.0306	2.8263	2.7886	2.5327	3.5578
SG $60^oF/60^oF$	0.74088	0.75222	0.76107	0.77486	0.79129	0.80665	0.81837
API Gravity (^{o})	59.49	56.61	54.42	51.11	47.32	43.92	41.40
Density at 60^oF (gms/ml)	0.74017	0.75150	0.76034	0.77412	0.79053	0.80588	0.81758
Volume of Fraction (mls)	9.79	9.84	10.04	15.03	15.00	14.99	14.98

* RSH = Receiver + Stopper + Hanger

TABLE VIII (Continued)

HEMPEL TYPE DISTILLATION ON RESIDUE F

Fraction	1	2	3	4	5	6	7
Receiver	2B	3B	4B	5B	6B	7B	8B
Mass of Receiver (gms)	27.7437	27.3972	27.5957	29.1287	29.0649	29.0833	27.7933
Stopper	8	9	10	11	12	13	14
Mass of Stopper (gms)	1.2438	1.4066	1.4768	1.6079	1.1435	1.4346	1.2368
Mass of Hanger (gms)	3.1420	3.1420	3.1420	3.1420	3.1420	3.1420	3.1420
Mass of RSH (gms)	32.1295	31.9458	32.2145	33.8786	33.3504	33.6599	32.1721
Mass of Fraction + RSH (gms)	39.4700	39.4215	39.6706	45.3781	44.9033	45.6462	45.8246
Mass of RSH (gms)	32.1295	31.9458	32.2145	33.8786	33.3504	33.6599	32.1721
Mass of Fraction (gms)	7.3405	7.4757	7.4561	11.4995	11.5529	11.9863	13.6525
Pycnometer	A	H	J	D	K	B	C
Mass of Pyc. + Sample (gms)	16.0594	17.1024	15.2741	17.2738	15.7410	14.2687	16.9165
Mass of Pyc. (gms)	13.2900	14.6170	12.9503	15.0672	13.5339	12.2235	14.0033
Mass of Sample at $60^{o}F$ (gms)	2.7694	2.4854	2.3238	2.2066	2.2071	2.0452	2.9132
M.E.V.W. at $60^{o}F$ (gms)	3.7134	3.2904	3.0306	2.8263	2.7886	2.5327	3.5578
SG $60^{o}F/60^{o}F$	0.74579	0.75535	0.76678	0.78074	0.79147	0.80752	0.81882
API Gravity (^{o})	58.23	55.83	53.04	49.74	47.28	43.73	41.31
Density at $60^{o}F$ (gms/ml)	0.74507	0.75463	0.76604	0.77999	0.79071	0.80675	0.81803
Volume of Fraction (mls)	9.85	9.91	9.73	14.74	14.61	14.86	16.69

* RSH = Receiver + Stopper + Hanger

TABLE VIII (Continued)

HEMPEL TYPE DISTILLATION ON RESIDUE A

Fraction	1	2	3	4	5	6
Receiver	2B	3B	4B	5B	6B	7B
Mass of Receiver (gms)	27.7437	27.3972	27.5957	29.1287	29.0649	29.0833
Stopper	8	9	10	11	12	13
Mass of Stopper (gms)	1.2438	1.4066	1.4768	1.6079	1.1435	1.4346
Mass of Hanger (gms)	3.1420	3.1420	3.1420	3.1420	3.1420	3.1420
Mass of RSH (gms)	32.1295	31.9458	32.2145	33.8786	33.3504	33.6599
Mass of Fraction + RSH (gms)	39.5751	39.4370	39.8493	41.5482	49.3385	45.9530
Mass of RSH (gms)	32.1295	31.9458	32.2145	33.8786	33.3504	33.6599
Mass of Fraction (gms)	7.4456	7.4912	7.6348	7.6696	15.9881	12.2931
Pycnometer	A	C	H	J	D	K
Mass of Pyc. + Sample (gms)	16.1169	16.7544	17.2105	15.3831	17.3606	15.8270
Mass of Pyc. (gms)	13.2900	14.0033	14.6170	12.9503	15.0672	13.5339
Mass of Sample at 60°F (gms)	2.8269	2.7511	2.5935	2.4328	2.2934	2.2931
M.E.V.W. at 60°F (gms)	3.7134	3.5578	3.2904	3.0306	2.8263	2.7886
SG 60°F/60°F	0.76127	0.77326	0.78820	0.80275	0.81145	0.82231
API Gravity (°)	54.37	51.49	48.02	44.77	42.88	40.58
Density at 60°F (gms/ml)	0.76054	0.77252	0.78744	0.80198	0.81067	0.82152
Volume of Fraction (mls)	9.79	9.70	9.70	9.56	19.72	14.96

* RSH = Receiver + Stopper + Hanger

TABLE IX

PROCESSED DATA

ENGLER TYPE DISTILLATION ON TWLCC2 CRUDE OIL

Fraction	Charge	0	1	2	3	4	5	6	7	Btms.
Vapor Temp. ($^{\circ}F$)		IBP 80	184	208	234	270	312	361	425	
Vapor Temp. at 760 mm Hg ($^{\circ}F$)		IBP 83	188	212	238	275	317	366	431	
Mass of Fraction (gms)	274.15	5.18	7.1583	6.8087	7.5073	14.8072	14.7364	15.2733	19.8127	182.87
Cum. Mass of Btms. (gms)	274.15		268.97	261.82	255.01	247.50	232.69	217.96	202.68	182.87
Cum. Mass Percent Btms. (%)	100.00		98.11	95.50	93.02	90.28	84.88	79.50	73.93	66.70
API Gravity ($^{\circ}$)	35.45		70.87	65.48	61.03	56.52	52.44	47.72	41.94	25.54
Density at $60^{\circ}F$ (gms/ml)	0.84673		0.69853	0.71765	0.73425	0.75187	0.76853	0.78878	0.81507	0.90021
Volume (mls)	323.77		10.25	9.49	10.22	19.69	19.17	19.36	24.31	203.14
Cum. Mass Percent of Chg. Dist. (%)		1.89	4.50	6.98	9.72	15.12	20.50	26.07	33.30	
Cum. Mass Percent at Midpoint of Fraction (%)			3.20	5.74	8.35	12.42	17.81	23.29	29.69	

[α] Fraction 0 obtained by difference in all cases.

Btms. = Distillation Bottoms
Chg. Dist. = Charge Distilled
Cum. = Cumulative
IBP = Initial Boiling Point
Temp. = Temperature
Vapor temperatures corrected to 760 mm Hg by Sydney Young equation (4).

TABLE IX (Continued)

ENGLER TYPE DISTILLATION ON RESIDUE Ha

Fraction	Charge	0	1	2	3	4	5	6	7	Btms.
Vapor Temp. (^{o}F)		IBP 100	191	220	239	281	324	377	425	
Vapor Temp. at 760 mm Hg (^{o}F)		IBP 104	196	225	244	286	330	383	431	
Mass of Fraction (gms)	269.05	3.12	6.8576	7.1137	7.1128	15.1636	15.4561	15.9391	17.0058	181.28
Cum. Mass of Btms. (gms)	269.05		265.93	259.07	251.96	244.84	229.68	214.22	198.29	181.28
Cum. Mass Percent Btms. (%)	100.00		98.84	96.29	93.65	91.00	85.37	79.62	73.70	67.38
API Gravity (°)	34.62		68.14	59.18	56.43	48.94	46.01	45.15	39.54	25.50
Density at $60^{o}F$ (gms/ml)	0.85097		0.70810	0.74136	0.75220	0.78346	0.79637	0.80027	0.82652	0.90038
Volume (mls)	316.17		9.68	9.60	9.46	19.35	19.41	19.92	20.58	201.34
Cum. Mass Percent of Chg. Dist. (%)		1.16	3.71	6.35	9.00	14.63	20.38	26.30	32.62	
Cum. Mass Percent at Midpoint of Fraction (%)			2.44	5.03	7.68	11.82	17.51	23.34	29.46	

TABLE IX (Continued)

ENGLER TYPE DISTILLATION ON RESIDUE G

Fraction	Charge	0	1	2	3	4	5	6	7	Btms.
Vapor Temp. (^{o}F)		IBP 130	210	230	250	286	330	388	425	
Vapor Temp. at 760 mm Hg (^{o}F)		IBP 134	215	235	255	291	336	394	431	
Mass of Fraction (gms)	280.67	19.49	7.8428	7.3304	7.9941	14.9794	15.5228	15.8723	13.1730	178.47
Cum. Mass of Btms. (gms)	280.67		261.18	253.34	246.01	238.02	223.04	207.52	191.64	178.47
Cum. Mass Percent Btms. (%)	100.00		93.06	90.26	87.65	84.80	79.47	73.94	68.28	63.59
API Gravity (^{o})	33.89		63.80	60.80	57.46	54.88	50.05	45.71	41.77	25.58
Density at 60^{o}F (gms/ml)	0.85475		0.72380	0.73514	0.74811	0.75846	0.77867	0.79771	0.81588	0.89994
Volume (mls)	328.37		10.83	9.97	10.69	10.01	19.94	19.90	16.15	198.31
Cum. Mass Percent of Chg. Dist. (%)		6.94	9.74	12.35	15.20	20.53	26.06	31.72	36.41	
Cum. Mass Percent at Midpoint of Fraction (%)			8.34	11.05	13.78	17.87	23.30	28.89	34.07	

TABLE IX (Continued)

ENGLER TYPE DISTILLATION ON RESIDUE B

Fraction	Charge	0	1	2	3	4	5	6	7	Btms.
Vapor Temp. (°F)		IBP 158	212	238	245	291	337	386	425	
Vapor Temp. at 760 mm Hg (°F)		IBP 162	216	243	250	296	342	391	431	
Mass of Fraction (gms)	274.47	1.74	6.8670	6.8715	6.9459	14.7816	15.2028	15.4454	12.4837	194.13
Cum. Mass of Btms. (gms)	274.47		272.73	265.86	258.99	252.04	237.26	222.06	206.61	194.13
Cum. Mass Pergent Btms. (%)	100.00		99.37	96.86	94.36	91.83	86.44	80.91	75.28	70.73
API Gravity ( )	33.12		55.15	57.85	54.70	53.80	49.40	45.02	41.68	25.63
Density at 60°F (gms/ml)	0.85872		0.75736	0.74658	0.75922	0.76288	0.78147	0.80086	0.81627	0.89969
Volume (mls)	319.63		9.07	9.20	9.15	19.38	19.45	19.29	15.29	215.77
Cum. Mass Percent of Chg. Dist. (%)		0.63	3.14	5.64	8.17	13.56	19.09	24.72	29.27	
Cum. Mass Percent at Midpoint of Fraction (%)			1.89	4.39	6.91	10.87	16.33	21.91	27.00	

TABLE IX (Continued)

ENGLER TYPE DISTILLATION ON RESIDUE C

Fraction	Charge	0	1	2	3	4	5	6	7	Btms.
Vapor Temp. (^{o}F)		IBP 160	223	250	267	310	357	397	425	
Vapor Temp. at 760 mm Hg (^{o}F)		IBP 164	227	255	272	315	362	403	431	
Mass of Fraction (gms)	275.45	1.49	7.2286	7.4690	7.3839	15.7159	15.4157	15.6103	9.3385	195.80
Cum. Mass of Btms. (gms)	275.45		273.96	266.73	259.26	251.88	236.16	220.75	205.14	195.80
Cum. Mass Percent Btms. (%)	100.00		99.46	96.83	94.12	91.44	85.74	80.14	74.47	71.08
API Gravity (^{o})	32.55		59.17	56.76	55.45	52.37	48.14	43.76	41.00	25.43
Density at 60^{o}F (gms/ml)	0.86169		0.74142	0.75089	0.75615	0.76882	0.78691	0.80659	0.81952	0.90082
Volume (mls)	319.66		9.75	9.95	9.77	20.44	19.59	19.35	11.40	217.36
Cum. Mass Percent of Chg. Dist. (%)		0.54	3.17	5.88	8.56	14.26	19.86	25.53	28.92	
Cum. Mass Percent at Midpoint of Fraction (%)			1.86	4.53	7.22	11.41	17.06	22.70	27.23	

TABLE IX (Continued)

ENGLER TYPE DISTILLATION ON RESIDUE D

Fraction	Charge	0	1	2	3	4	5	6	7	Btms.
Vapor Temp. (^oF)		IBP 184	240	257	271	320	361	399	425	
Vapor Temp. at 760 mm Hg (^oF)		IBP 189	245	262	276	326	367	405	432	
Mass of Fraction (gms)	279.09	4.05	7.7899	7.6653	7.7028	15.5206	15.6181	12.2764	10.0606	198.41
Cum. Mass of Btms. (gms)	279.09		275.04	267.25	259.59	251.89	236.37	220.75	208.47	198.41
Cum. Mass Percent Btms. (%)	100.00		98.55	95.76	93.01	90.25	84.69	79.10	74.70	71.09
API Gravity (°)	32.16		58.03	55.47	53.94	51.14	47.36	43.86	41.43	25.43
Density at 60^oF (gms/ml)	0.86377		0.74585	0.75608	0.76232	0.77402	0.79035	0.80612	0.81747	0.90081
Volume (mls)	323.11		10.44	10.14	10.10	20.05	19.76	15.23	12.31	220.26
Cum. Mass Percent of Chg. Dist. (%)		1.45	4.24	6.99	9.75	15.31	20.90	25.30	28.91	
Cum. Mass Percent at Midpoint of Fraction (%)			2.85	5.62	8.37	12.53	18.11	23.10	27.11	

TABLE IX (Continued)

ENGLER TYPE DISTILLATION ON RESIDUE E

Fraction	Charge	0	1	2	3	4	5	6	7	Btms.
Vapor Temp. (°F)		IBP 194	245	265	283	315	360	392	425	
Vapor Temp. at 760 mm Hg (°F)		IBP 199	250	270	288	321	366	398	431	
Mass of Fraction (gms)	275.46	0.72	7.2699	7.5112	7.4248	11.6967	15.5608	11.9963	11.2843	202.00
Cum. Mass of Btms. (gms)	275.46		274.74	267.47	259.96	252.54	240.84	225.28	213.28	202.00
Cum. Mass Percent Btms. (%)	100.00		99.74	97.10	94.37	91.68	87.43	81.78	77.43	73.33
API Gravity (°)	31.86		55.77	54.51	52.83	50.17	47.62	44.00	41.17	25.58
Density at 60°F (gms/ml)	0.86536		0.75486	0.75997	0.76690	0.77815	0.78921	0.80552	0.81868	0.89996
Volume (mls)	318.32		9.63	9.88	9.68	15.03	19.72	14.89	13.78	224.45
Cum. Mass Percent of Chg. Dist. (%)		0.26	2.90	5.63	8.32	12.57	18.22	22.57	26.67	
Cum. Mass Percent at Midpoint of Fraction (%)			1.58	4.27	6.98	10.45	15.40	20.40	24.62	

TABLE IX (Continued)

ENGLER TYPE DISTILLATION ON RESIDUE F

Fraction	Charge	0	1	2	3	4	5	6	7	Btms.
Vapor Temp. (^{o}F)		IBP 218	257	276	295	327	358	397	425	
Vapor Temp. at 760 mm Hg (^{o}F)		IBP 223	262	281	300	333	364	403	431	
Mass of Fraction (gms)	275.23	0.58	7.1853	6.9281	7.4405	12.0008	11.7869	11.7221	11.8339	205.75
Cum. Mass of Btms. (gms)	275.23		274.65	267.46	260.53	253.09	241.09	229.31	217.58	205.75
Cum. Mass Percent Btms. (%)	100.00		99.79	97.18	94.66	91.96	87.60	83.32	79.05	74.76
API Gravity (^{o})	31.49		55.53	53.69	51.88	50.22	47.71	44.44	41.46	25.62
Density at 60^{o}F (gms/ml)	0.86734		0.75583	0.76337	0.77089	0.77790	0.78881	0.80347	0.81733	0.89971
Volume (mls)	317.33		9.51	9.08	9.65	15.43	14.94	14.59	14.48	228.68
Cum. Mass Percent of Chg. Dist. (%)		0.21	2.82	5.34	8.04	12.40	16.68	20.95	25.24	
Cum. Mass Percent at Midpoint of Fraction (%)			1.52	4.08	6.69	10.22	14.54	18.82	23.10	

TABLE IX (Continued)

ENGLER TYPE DISTILLATION ON RESIDUE A

Fraction	Charge	0	1	2	3	4	5	6	7	Btms.
Vapor Temp. (°F)		IBP 235	290	313	329	350	370	395	425	
Vapor Temp. at 760 mm Hg (°F)		IBP 240	295	318	334	355	376	401	431	
Mass of Fraction (gms)	279.21	2.19	7.5197	7.6579	7.7720	7.7952	7.3890	8.0580	12.3700	218.46
Cum. Mass of Btms. (gms)	279.21		277.02	269.50	261.84	254.07	246.28	238.89	230.83	218.46
Cum. Mass Percent Btms. (%)	100.00		99.20	96.52	93.78	91.00	88.21	85.56	82.67	78.24
API Gravity (°)	30.44		52.98	51.21	49.04	47.51	45.53	43.35	41.49	25.75
Density at 60°F (gms/ml)	0.87292		0.76627	0.77373	0.78301	0.78968	0.79851	0.80858	0.81719	0.89896
Volume (mls)	319.86		9.81	9.90	9.93	9.87	9.25	9.97	15.14	243.01
Cum. Mass Percent of Chg. Dist. (%)		0.78	3.48	6.22	9.00	11.79	14.44	17.33	21.76	
Cum. Mass Percent at Midpoint of Fraction (%)			2.13	4.85	7.61	10.40	13.12	15.89	19.55	

TABLE IX (Continued)

HEMPEL TYPE DISTILLATION ON TWLCC2 CRUDE OIL

Fraction	Charge	0	1	2	3	4	5	6	7	Btms.
Vapor Temp. (°F)		IBP 68	164	190	210	264	306	366	425	
Vapor Temp. at 760 mm Hg (°F)		IBP 71	168	194	214	269	311	371	431	
Mass of Fraction (gms)	270.18	5.78	6.7185	7.1431	7.3964	15.1886	15.0987	15.7824	19.1497	177.92
Cum. Mass of Btms. (gms)	270.18		264.40	257.68	250.54	243.14	227.95	212.85	197.07	177.92
Cum. Mass Percent Btms. (%)	100.00		97.86	95.37	92.73	89.99	84.37	78.78	72.94	65.85
Obs. API Gravity (°)	35.45		76.01	62.22	60.61	55.99	51.68	56.55	41.30	25.22
Corr. API Gravity (°)	35.45				59.99	56.38	51.68	46.82	41.30	25.22
Obs. Density at 60°F (gms/ml)	0.84673		0.68123	0.72972	0.73583	0.75398	0.77172	0.79394	0.81806	0.90203
Corr. Density at 60°F (gms/ml)	0.84673				0.73823	0.75242	0.77172	0.73673	0.81806	0.90203
Obs. Volume at 60°F (mls)	319.09		9.86	9.79	10.05	20.14	19.56	19.88	23.41	197.24
Corr. Volume at 60°F (mls)	319.09				10.02	20.19	19.56	21.42	23.41	197.24
Cum. Volume of Btms. (mls)	319.09				291.86	281.82	261.63	242.07	220.65	197.24
Cum. Volume Percent Btms. (%)	100.00				91.47	88.32	81.99	75.86	69.15	61.81
Cum. Mass Percent of Chg. Dist. (%)		2.14	4.63	7.27	10.01	15.63	21.22	27.06	34.15	
Cum. Mass Percent at Midpoint of Fraction (%)			3.39	5.95	8.64	12.82	18.43	24.14	30.61	
Mass X API Gravity (gms °)					443.71	856.33	780.30	738.93	790.88	4487.14
Cum. Mass X API Gravity Btms. (gms °)					8097.29	7653.58	6797.25	6016.95	5278.02	4487.14
Btms. API Gravity (°)	35.45				32.32	31.48	29.82	28.27	26.78	25.22

Obs. = Observed
Corr. = Corrected

TABLE IX (Continued)

HEMPEL TYPE DISTILLATION ON RESIDUE Ha

Fraction	Charge	0	1	2	3	4	5	6	7	8	Btms.
Vapor Temp. (°F)		IBP 79	173	198	217	236	285	334	388	425	
Vapor Temp. at 760 mm Hg (°F)		IBP 83	181	203	222	241	290	340	394	431	
Mass of Fraction (gms)	271.23	2.75	6.7380	7.0760	7.1702	7.1399	15.1998	15.5152	15.7948	12.2640	181.58
Cum. Mass of Btms. (gms)	271.23		268.48	261.74	254.66	247.49	240.35	225.15	209.64	193.84	181.58
Cum. Mass Percent Btms. (%)	100.00		98.99	96.50	93.89	91.25	88.61	83.01	77.29	71.47	66.95
Obs. API Gravity (°)	34.62		72.89	60.22	56.59	50.67	50.10	47.41	40.97	40.38	25.20
Corr. API Gravity (°)	34.62				59.75	57.23	53.75	49.10	44.47	40.38	25.20
Obs. Density at 60°F (gms/ml)	0.85097		0.69164	0.73735	0.75157	0.77599	0.77842	0.79014	0.81963	0.82246	0.90214
Corr. Density at 60°F (gms/ml)	0.85097				0.73916	0.74903	0.76310	0.78275	0.80334	0.82246	0.90214
Obs. Volume at 60°F (mls)	318.73		9.74	9.60	9.54	9.20	19.53	19.64	19.27	14.91	201.28
Corr. Volume at 60°F (mls)	318.73				9.70	9.53	19.92	19.82	19.66	14.91	201.28
Cum. Volume of Btms. (mls)	318.73				294.82	285.12	275.59	255.67	235.85	216.19	201.28
Cum. Volume Percent Btms. (%)	100.00				92.50	89.46	86.47	80.22	74.00	67.83	63.15
Cum. Mass Percent of Chg. Dist. (%)		1.01	3.50	6.11	8.75	11.39	16.99	22.71	28.53	33.05	
Cum. Mass Percent at Midpoint of Fraction (%)			2.26	4.81	7.43	10.07	14.19	19.85	25.62	30.79	
Mass X API Gravity (gms °)					428.42	410.76	816.99	761.80	702.39	495.22	4575.82
Cum. Mass X API Gravity Btms. (gms °)					8191.40	7762.98	7352.22	6535.23	5773.43	5071.04	4575.82
Btms. API Gravity (°)	34.62				32.17	31.37	30.59	29.03	27.54	26.16	25.20

TABLE IX (Continued)

HEMPEL TYPE DISTILLATION ON RESIDUE G

Fraction	Charge	0	1	2	3	4	5	6	7	Btms.
Vapor Temp. (^{o}F)		IBP 90	177	200	220	268	313	369	425	
Vapor Temp. at 760 mm Hg (^{o}F)		IBP 94	182	205	225	273	319	375	431	
Mass of Fraction (gms)	272.45	1.42	6.6948	7.1045	7.3060	15.0675	15.4296	16.0304	17.4971	185.90
Cum. Mass of Btms. (gms)	272.45		271.03	264.34	257.23	249.92	234.86	219.43	203.40	185.90
Cum. Mass Percent Btms. (%)	100.00		99.48	97.02	94.41	91.73	86.20	80.54	74.66	68.23
Obs. API Gravity (o)	33.89		70.47	60.39	55.87	51.72	92.86	43.66	41.36	25.37
Corr. API Gravity (^{o})	33.89				59.00	55.23	51.38	45.85	41.36	25.37
Obs. Density at $60^{o}F$ (gms/ml)	0.85475		0.69994	0.73670	0.75448	0.77154	0.63065	0.80705	0.81778	0.90113
Corr. Density at $60^{o}F$ (gms/ml)	0.85475				0.74207	0.75705	0.77299	0.79709	0.81778	0.90113
Obs. Volume at $60^{o}F$ (mls)	318.75		9.56	9.64	9.68	19.53	24.47	19.86	21.40	206.30
Corr. Volume at $60^{o}F$ (mls)	318.75				9.85	19.90	19.96	20.11	21.40	206.30
Cum. Volume of Btms. (mls)	318.75				297.52	287.67	267.77	247.81	227.70	2[illegible]6.30
Cum. Volume Percent Btms. (%)	100.00				93.34	90.25	84.01	77.75	71.44	64.72
Cum. Mass Percent of Chg. Dist. (%)		0.52	2.98	5.59	8.27	13.80	19.36	25.34	31.77	
Cum. Mass Percent at Midpoint of Fraction (%)			1.75	4.29	6.93	11.04	15.58	22.35	28.56	
Mass X API Gravity (gms ^{o})					431.05	832.18	792.77	734.99	723.68	4716.08
Cum. Mass X API Gravity Btms. (gms ^{o})					8230.75	7799.70	6967.52	6174.75	5439.76	4716.08
Btms. API Gravity (^{o})	33.89				32.00	31.21	29.66	28.14	26.74	25.37

TABLE IX (Continued)

HEMPEL TYPE DISTILLATION ON RESIDUE B

Fraction	Charge	0	1	2	3	4	5	6	7	Btms.
Vapor Temp. (°F)		IBP 90	193	217	238	285	330	385	425	
Vapor Temp. at 760 mm Hg (°F)		IBP 94	197	223	243	290	335	390	431	
Mass of Fraction (gms)	274.64	2.03	6.8800	7.1052	7.2867	15.1387	15.6293	15.8559	12.3987	192.32
Cum. Mass of Btms. (gms)	274.64		272.61	265.73	258.63	251.34	236.20	220.57	204.72	192.32
Cum. Mass Percent Btms. (%)	100.00		99.26	96.76	94.17	91.52	86.00	80.31	74.54	70.07
Obs. API Gravity (°)	33.12		62.14	59.65	56.69	54.35	49.55	44.62	41.27	25.30
Corr. API Gravity (°)	33.12				57.32	53.73	48.84	44.40	41.27	25.30
Obs. Density at 60°F (gms/ml)	0.85872		0.73003	0.73956	0.75118	0.76065	0.78079	0.80264	0.81824	0.90158
Corr. Density at 60°F (gms/ml)	0.85872				0.74867	0.76319	0.78388	0.80366	0.81824	0.90158
Obs. Volume at 60°F (mls)	319.82		9.42	9.61	9.70	19.90	20.02	19.75	15.15	213.31
Corr. Volume at 60°F (mls)	319.82				9.73	19.84	19.94	19.73	15.15	213.31
Cum. Volume of Btms. (mls)	319.82				297.70	287.97	268.13	248.19	228.46	213.31
Cum. Volume Percent Btms. (%)	100.00				93.08	90.04	83.84	77.60	71.43	66.70
Cum. Mass Percent of Chg. Dist. (%)		0.74	3.24	5.83	8.48	14.00	19.69	25.46	29.93	
Cum. Mass Percent at Midpoint of Fraction (%)			1.99	4.54	7.16	11.24	16.85	22.58	27.70	
Mass X API Gravity (gms °)					417.67	813.40	763.34	704.00	511.69	4865.70
Cum. Mass X API Gravity Btms. (gms °)					8075.80	7658.13	6844.73	6081.39	5377.39	4865.70
Btms. API Gravity (°)	33.12				31.23	30.47	28.98	27.57	26.27	25.30

TABLE IX (Continued)

HEMPEL TYPE DISTILLATION ON RESIDUE C

Fraction	Charge	0	1	2	3	4	5	6	7	Btms.
Vapor Temp. (^{o}F)		IBP 150	203	225	246	295	345	397	425	
Vapor Temp. at 760 mm Hg (^{o}F)		IBP 154	207	229	251	300	350	403	431	
Mass of Fraction (gms)	274.65	0.88	7.0450	7.1578	7.3690	15.2395	15.5938	15.7284	10.3145	195.32
Cum. Mass of Btms. (gms)	274.65		273.77	266.72	259.57	252.20	236.96	221.36	205.63	195.32
Cum. Mass Percent Btms. (%)	100.00		99.68	97.11	94.51	91.83	86.28	80.60	74.87	71.12
Obs. API Gravity (°)	32.55		62.23	58.63	56.84	53.29	48.48	43.81	40.93	25.25
Corr. API Gravity (°)	32.55				56.25	52.58	47.66	44.63	40.93	25.25
Obs. Density at 60^{o}F (gms/ml)	0.86169		0.72968	0.74352	0.75058	0.76501	0.78545	0.80639	0.81983	0.90186
Corr. Density at 60^{o}F (gms/ml)	0.86169				0.75294	0.76795	0.78904	0.80261	0.81983	0.90186
Obs. Volume at 60^{o}F (mls)	318.73		9.65	9.63	9.82	19.42	19.85	19.50	12.58	216.57
Corr. Volume at 60^{o}F (mls)	318.73				9.79	19.84	19.76	19.60	12.58	216.57
Cum. Volume of Btms. (mls)	318.73				298.14	288.35	268.51	248.75	229.15	216.57
Cum. Volume Percent Btms. (%)	100.00				93.54	90.47	84.24	78.04	71.89	67.95
Cum. Mass Percent of Chg. Dist. (%)		0.32	2.89	5.49	8.17	13.72	19.40	25.13	28.89	
Cum. Mass Percent at Midpoint of Fraction (%)			1.61	4.19	6.83	10.95	16.56	22.27	27.01	
Mass X API Gravity (gms °)					414.51	801.29	743.20	701.96	402.17	4931.83
Cum. Mass X API Gravity Btms. (gms °)					7994.96	7580.45	6779.16	6035.96	5334.00	4931.83
Btms. API Gravity (°)	32.55				30.80	30.06	28.61	27.27	25.94	25.25

TABLE IX (Continued)

HEMPEL TYPE DISTILLATION ON RESIDUE D

Fraction	Charge	0	1	2	3	4	5	6	7	Btms.
Vapor Temp. (°F)		IBP 190	210	232	253	300	350	390	425	
Vapor Temp. at 760 mm Hg (°F)		IBP 195	215	237	258	306	356	396	432	
Mass of Fraction (gms)	273.78	1.09	6.7033	8.0908	7.3683	15.3134	15.7339	11.6763	12.3078	195.50
Cum. Mass of Btms. (gms)	273.78		272.69	265.99	257.90	250.33	235.22	219.48	207.81	195.50
Cum. Mass Percent Btms. (%)	100.00		99.60	97.15	94.20	91.51	85.92	80.17	75.90	71.41
Obs. API Gravity (°)	32.16		59.51	57.23	54.67	49.97	40.83	38.44	40.72	25.08
Corr. API Gravity (°)	32.16				54.67	51.05	46.44	43.06	40.75	25.08
Obs. Density at 60°F (gms/ml)	0.86377		0.74007	0.74904	0.75932	0.77900	0.82030	0.83187	0.82081	0.90285
Corr. Density at 60°F (gms/ml)	0.86377				0.75932	0.77439	0.79445	0.80983	0.82069	0.90285
Obs. Volume at 60°F (mls)	316.96		9.06	10.80	9.70	19.66	19.18	14.04	14.99	216.54
Corr. Volume at 60°F (mls)	316.96				9.70	19.77	19.80	14.42	15.00	216.54
Cum. Volume of Btms. (mls)	316.96				295.23	285.53	265.76	245.96	231.54	216.54
Cum. Volume Percent Btms. (%)	100.00				93.14	90.08	83.85	77.60	73.05	68.32
Cum. Mass Percent of Chg. Dist. (%)		0.40	2.85	5.80	8.49	14.08	19.83	24.10	28.92	
Cum. Mass Percent at Midpoint of Fraction (%)			1.63	4.33	7.15	11.29	16.96	21.97	26.51	
Mass X API Gravity (gms °)					402.82	781.75	730.68	502.78	501.54	4903.14
Cum. Mass X API Gravity Btms. (gms °)					7822.71	7419.89	6638.14	5907.46	5404.68	4903.14
Btms. API Gravity (°)	32.16				30.33	29.62	28.22	26.92	26.01	25.08

TABLE IX (Continued)

HEMPEL TYPE DISTILLATION ON RESIDUE E

Fraction	Charge	0	1	2	3	4	5	6	7	Btms.
Vapor Temp. (°F)		IBP 105	220	246	270	310	348	391	425	
Vapor Temp. at 760 mm Hg (°F)		IBP 109	225	251	275	316	354	397	431	
Mass of Fraction (gms)	261.23	0.78	7.2480	7.3920	7.6328	11.6351	11.8583	12.0821	12.2472	190.35
Cum. Mass of Btms. (gms)	261.23		260.45	253.20	245.81	238.17	226.54	214.68	202.60	190.35
Cum. Mass Percent Btms.(%)	100.00		99.70	96.93	94.10	91.17	86.72	82.18	77.56	72.87
Obs. API Gravity (°)	31.86		59.49	56.61	54.42	51.11	47.32	43.92	41.40	25.30
Corr. API Gravity (°)	31.86				53.66	50.38	46.63	44.20	41.16	25.30
Obs. Density at 60°F (gms/ml)	0.86536		0.74017	0.75150	0.76034	0.77412	0.79053	0.80588	0.81758	0.90157
Corr. Density at 60°F (gms/ml)	0.86536				0.76347	0.77724	0.79360	0.80458	0.81921	0.90157
Obs. Volume at 60°F (mls)	301.87		9.79	9.84	10.04	15.03	15.00	14.99	14.98	211.13
Corr. Volume at 60°F (mls)	301.87				10.00	14.97	14.94	15.02	14.95	211.13
Cum. Volume of Btms. (mls)	301.87				281.01	271.01	256.04	241.10	226.08	211.13
Cum. Volume Percent Btms. (%)	100.00				93.09	89.78	84.82	79.87	74.89	69.94
Cum. Mass Percent of Chg. Dist. (%)		0.30	3.07	5.90	8.83	13.28	17.82	22.44	27.13	
Cum. Mass Percent at Midpoint of Fraction (%)			1.69	4.49	7.37	11.06	15.55	20.13	24.79	
Mass X API Gravity (gms °)					409.58	586.18	552.95	534.03	504.09	4815.86
Cum. Mass X API Gravity Btms. (gms °)					7402.69	6993.11	6406.93	5853.98	5319.95	4815.86
Btms. API Gravity (°)	31.86				30.12	29.36	28.28	27.27	26.26	25.30

TABLE IX (Continued)

HEMPEL TYPE DISTILLATION ON RESIDUE F

Fraction	Charge	0	1	2	3	4	5	6	7	Btms.
Vapor Temp. (°F)		IBP 186	235	252	275	308	345	385	425	
Vapor Temp. at 760 mm Hg (°F)		IBP 191	240	257	280	314	351	391	431	
Mass of Fraction (gms)	271.00	0.44	7.3405	7.4757	7.4561	11.4995	11.5529	11.9863	13.6525	199.60
Cum. Mass of Btms. (gms)	271.00		270.56	263.22	255.75	248.29	236.79	225.24	213.25	199.60
Cum. Mass Percent Btms. (%)	100.00		99.84	97.13	94.37	91.62	87.38	83.11	78.69	73.65
Obs. API Gravity (°)	31.49		58.23	55.83	53.04	49.74	47.28	43.73	41.31	25.29
Corr. API Gravity (°)	31.49				53.04	49.74	46.32	43.73	41.31	25.29
Obs. Density at 60°F (gms/ml)	0.86734		0.74507	0.75463	0.76604	0.77999	0.79071	0.80675	0.81803	0.90159
Corr. Density at 60°F (gms/ml)	0.86734				0.76604	0.77999	0.79499	0.80675	0.81803	0.90159
Obs. Volume at 60°F (mls)	312.45		9.85	9.91	9.73	14.74	14.61	14.86	16.69	221.39
Corr. Volume at 60°F (mls)	312.45				9.73	14.74	14.53	14.86	16.69	221.39
Cum. Volume of Btms. (mls)	312.45				291.94	282.21	267.47	252.94	238.08	221.39
Cum. Volume Percent Btms. (%)	100.00				93.44	90.32	85.60	80.95	76.20	70.86
Cum. Mass Percent of Chg. Dist. (%)		0.16	2.87	5.63	8.38	12.62	16.89	21.31	26.35	
Cum. Mass Percent at Midpoint of Fraction (%)			1.52	4.25	7.01	10.50	14.76	19.10	23.83	
Mass X API Gravity (gms °)					395.47	571.99	535.13	524.16	563.98	5047.88
Cum. Mass X API Gravity Btms. (gms °)					7638.61	7243.14	6671.15	6136.02	5611.86	5047.88
Btms. API Gravity (°)	31.49				29.87	29.17	28.17	27.24	26.32	25.29

TABLE IX (Continued)

HEMPEL TYPE DISTILLATION ON RESIDUE A

Fraction	Charge	0	1	2	3	4	5	6	Btms.
Vapor Temp. (°F)		IBP 98	258	285	311	334	389	425	
Vapor Temp. at 760 mm Hg (°F)		IBP 102	263	290	316	339	393	431	
Mass of Fraction (gms)	248.46	0.49	7.4456	7.4912	7.6348	7.6696	15.9881	12.2931	189.45
Cum. Mass of Btms. (gms)	248.46		247.97	240.53	233.04	225.40	217.73	201.74	189.45
Cum. Mass Percent Btms. (%)	100.00		99.80	96.81	93.79	90.72	87.63	81.20	76.25
Obs. API Gravity (°)	30.44		54.37	51.49	48.02	44.77	42.88	40.58	25.05
Corr. API Gravity (°)	30.44		54.37	51.23	48.02	45.44	42.88	40.58	25.05
Obs. Density at 60°F (gms/ml)	0.87292		0.76054	0.77252	0.78744	0.80198	0.81067	0.82152	0.90300
Corr. Density at 60°F (gms/ml)	0.87292		0.76054	0.77363	0.78744	0.79894	0.81067	0.82152	0.90300
Obs. Volume at 60°F (mls)	284.63		9.79	9.70	9.70	9.56	19.72	14.96	209.80
Corr. Volume at 60°F (mls)	284.63		9.79	9.68	9.70	9.60	19.72	14.96	209.80
Cum. Volume of Btms. (mls)	284.63		283.22	273.46	263.78	254.08	244.48	224.76	209.80
Cum. Volume Percent Btms. (%)	100.00		99.50	96.08	92.67	89.27	85.89	78.97	73.71
Cum. Mass Percent of Chg. Dist. (%)		0.20	3.19	6.21	9.28	12.37	18.80	23.75	
Cum. Mass Percent at Midpoint of Fraction (%)			1.70	4.70	7.75	10.83	15.59	21.28	
Mass X API Gravity (gms °)			404.82	383.77	366.62	348.51	685.57	498.85	4745.72
Cum. Mass X API Gravity Btms. (gms °)			7433.86	7029.04	6645.27	6278.65	5930.15	5244.57	4745.72
Btms. API Gravity (°)	30.44		29.98	29.22	28.52	27.86	27.24	26.00	25.05

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